INVESTIGATIONS IN SOIL MANAGEMENT

BEING THREE OF SIX PAPERS

ON THE

Influence of Soil Management

UPON THE

Water-Soluble Salts in Soils

AND THE

Yield of Crops

BY

F. H. KING

"B" **Amounts of Plant Food Readily Recoverable from Field Soils by Distilled Water.**

"C" **Relations of Crop Yields to Amounts of Water-Soluble Plant-Food Materials Recovered from Soils.**

"D" **Absorption of Water-Soluble Salts by Different Soil Types.**

"E" **Influence of Farm Yard Manure upon the Water-Soluble Salts of Soils.**

"F" **Movement of Water-Soluble Salts in Soils.**

"G" **Relations of Differences of Yield on Eight Soil Types to Difference of Climatological Environment.**

The six papers constitute the Report of the Chief of the Division of Soil Management, for 1902 and 1903, but the three here printed have been refused Departmental publication by the Chief of the Bureau of Soils.

MADISON, WIS.:

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1904.

PREFACE.

The three papers here presented form but portions of a single investigation systematically planned to throw new light upon important problems in soil management, and the full significance of them, as parts of a whole, can only be seen by considering them in connection with the three papers from which they have been severed in that they were not allowed to appear as Departmental publications.

It is believed that the subjects of the six papers, and the data presented in them, merit adequate discussion but this was withheld to avoid, as far as possible, antagonizing the published views of the Bureau and the three papers are presented here as they were originally submitted.

In addition to these statements it is due the writer and his associates in this investigation to say that the data presented have lost very much of fullness and value through changes in plan made in the midst of the investigation but over which we had no control.

F. H. King.

Madison, Wis., Aug. 18, 1904.

LETTERS OF SUBMITTAL.

WASHINGTON, D. C., June 20, 1904.

SIR: In order to test, in an adequate manner, the field methods which had been devised for the determination of soluble salts in soils, and in order to be able to study the same soil under conditions where the yields were certain to be measurably different, it was decided to develop systematic differences in each of the eight soils, chosen for the investigations of 1903, by the application of definite quantities of manure in multiple amounts upon different portions of the areas where crops were to be grown.

Manure was chosen to develop these differences because it is acknowledged to be the best general fertilizer known and because it is a universal by-product of the farm whose most economical use demands much fuller knowledge than is yet available. The quantities of manure chosen were small—5, 10, and 15 tons per acre—in order better to test the sensitiveness and reliability of the methods, by not developing too large differences in the soluble salt content of the soil, and in order to gain more definite knowledge of the relative and absolute efficiencies of manure when applied broadcast to soil in different amounts.

The results herewith submitted are those which relate to the influence of different amounts of manure upon the water-soluble salts which may be recovered from soils with distilled water; and those which show the absolute and relative efficiencies, the first season, of different amounts of manure when applied broadcast to soils and well plowed under.

The fitting of the soils, application of manure, planting and general care of the crops, were under the immediate charge of W. C. Palmer, J. W. Nelson, J. O. Belz and A. H. Snyder;

and the chemical determinations were made by them and by F. R. Pember and J. C. Hogenson.

F. H. KING,
Chief of the Division of Soil Management.

PROF. MILTON WHITNEY,
Chief of the Bureau of Soils.

WASHINGTON, D. C., June 27, 1904.

SIR: In our earlier investigations, relating to the influence of tillage, and especially to that of deep and shallow cultivation, upon the yields of crops, there were relations observed which made it appear that such tillage exerts an influence upon yield other than that due simply to the effect it may have upon soil moisture. Moreover, in investigating the causes of the relatively low fertility of so many of the Southern soils, it was felt, on account of the excessive surface washing which is characteristic of the region in question, that if notable amounts of readily water-soluble plant food materials are brought by capillarity to the surface during drying times, the carrying of these away in the surface drainage may be one of the causes of their low productive capacity.

It appeared very important, therefore, from the practical standpoint, to investigate the movements of plant food materials, as influenced by capillarity, in these Southern soils. The paper which is submitted herewith gives the results of investigations, relating to this subject, carried on during the seasons of 1902 and 1903.

This paper, like the other four which have been submitted, is the result of co-operative and concerted effort on the part of most of the men of this Division and credit is due J. O. Belz, W. C. Palmer, A. H. Snyder, J. W. Nelson, Dr. Oswald Schreiner, J. C. Hogenson, F. D. Stevens, H. L. Belden, A. T. Strahorn, F. R. Pember, Jay F. Warner, F. C. Schroeder and W. S. Lyman.

F. H. KING,
Chief of the Division of Soil Management.

PROF. MILTON WHITNEY,
Chief of the Bureau of Soils.

WASHINGTON, D. C., June 20, 1904.

SIR: In conducting investigations along the lines of those reported in the bulletins on "The Amounts of Plant Food Recoverable from Field Soils with Distilled Water," and on the "Relation of Crop Yields to the Amounts of Water-Soluble Plant Food Materials Recovered from Soils," the power of soils to absorb plant food materials from solutions, when brought in contact with them, could not be omitted from consideration; neither could the re-solution of such absorbed materials be ignored. Moreover, since it has been long recognized that the influence of both good soil management and bad soil management is cumulative in its effects upon soils to a marked degree, while the reasons for these tendencies are not sufficiently understood, it is of fundamental importance to ascertain whether the productive capacities of soils are, in any essential way, related to their absorptive and retentive powers over the essential plant food materials; and whether good soil management may not result in clothing the soil skeleton with heavier and heavier accumulations of these materials while the reverse tendency may not be associated with poor soil management.

The absorption studies submitted herewith, were made chiefly upon the 8 soil types which have contributed a large share of the data of the two former investigations whose results have been submitted, and they have, therefore, a value they would not otherwise possess. We have also incorporated so much of the results of investigations along these lines, made between 1845 and 1865, as will serve to indicate the nature of the results and the importance attached to this subject at that time.

The determinations for this work have been made chiefly by Mr. J. O. Belz, A. H. Snyder, J. W. Nelson, W. C. Palmer, F. R. Pember, and J. C. Hogenson, and the solutions used were prepared by Dr. Schreiner.

F. H. KING,

Chief of the Division of Soil Management.

PROF. MILTON WHITNEY,

Chief of the Bureau of Soils.

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BULLETIN "E."

Influence of Farm Yard Manure Upon Yield and Upon the Water-Soluble Salts of Soils.

In the comparative study, the results of which are here reported, an effort was made to measure the effect of three very moderate dressings of stable manure both upon the yield of crops and upon the water-soluble salts which could be recovered readily from the soils so treated.

The amounts of manure applied were at the rates of 5, 10 and 15 tons per acre, and these quantities were applied to 8 soil types upon 2-acre areas, subdivided in the manner indicated in Fig. 1.

The soils selected were the Norfolk Sandy Soil and Selma Silt Loam at Goldsboro, N. C.; the Norfolk Sand and Sassafras Sandy Loam at Upper Marlboro, Md.; the Hagerstown Clay Loam and Hagerstown Loam at Lancaster, Penn.; and the Janesville Loam and Miami Loam at Janesville, Wis. These soils are fully described in the Second and Fourth Reports of this Bureau.

The areas here considered were chosen primarily for a comparative study of the water-soluble salts of soils and their relations to yields, and the treatments here referred to were given in order to secure differences of yield within the same soil type. These phases of the study are reported in Bulletins "B"* and "C". As there stated, the soils were specially chosen with the view to having those strongly contrasted in their native productive capacities, in order that well marked differences might be dealt with. Such selection, too, is quite as satisfactory for the purposes of the study here made.

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*Bureau of Soils. "B," Amounts of Plant Food Readily Recoverable from Field Soils with Distilled Water. "C," Relation of Crop Yields to the Amounts of Water-Soluble Plant Food Materials Recovered from Soils.

POTATOES	FALLOW	CORN
0	Nothing applied.	0
5 Five tons	of stable manure	per acre. 5
10 Ten tons	of stable manure	per acre 10
15 Fifteen tons	of stable manure	per acre.15
F 300 lbs.	of acme guano	per acre. F
0	Nothing applied.	0
5 Five tons	of stable manure	per acre. 5
10 Ten tons	of stable manure	per acre. 10
15 Fifteen tons	of stable manure	per acre15
F 300 lbs.	of acme guano	per acre. F
0	Nothing applied.	0
5 Five tons	of stable manure	per acre. 5
10 Ten tons	of stable manure	per acre. 10
15 Fifteen tons	of stable manure	per acre 15
F 300 lbs.	of acme guano	per acre F
0	Nothing applied.	0
5 Five tons	of stable manure	per acre. 5
10 Ten tons	of stable manure	per acre. 10
15 Fifteen tons	of stable manure	per acre15
F 300 lbs.	of acme guano	per acre. F

FIG. 1.—Showing arrangement of plots to study effects of fertilization upon yield and upon the water-soluble salts in soil. The sub-plots had the width of six rows and were not separated by paths.

We shall have, therefore, for comparis n, four naturally strong soils and four others which, in native capacity, are weak. The Janesville and Lancaster soils constitute the stronger group, while the Goldsboro and Marlboro soils form the weaker group.

APPLICATION OF THE MANURE.

In order to secure a uniform quality of manure for the two soil types in each locality and for the different amounts applied, the manure to be used was first brought together into a single pile, spreading each load evenly over it until the required amount had been collected. Then, when applying the manure to the field, each load was distributed crosswise of the sub-plots in such a manner that proper aliquot portions fell upon each sub-plot treated. It happened at Janesville that the manure of the previous winter from a dairy herd could be taken direct from the yard where it had been piled. That used at Lancaster was taken from roofed stock yards, but that for Goldsboro and Marlboro had to be collected from various places about the city. Composite samples of the manures had been carefully taken for analyses but these have not been made.

The acme guano* used was purchased in one lot and subdivided for the four localities, so that this fertilizer was the same for the 8 soil types. The manure and fertilizer were applied broadcast and plowed under on all soils to a depth of 6 to 8 inches, about 3 weeks before planting.

SEED, PLANTING, AND CARE OF CROP.

The corn and potatoes used for seed were purchased of Northrup, King & Company, Minneapolis, Minnesota, Iowa Gold Mine being used for corn and Rural New Yorkers for potatoes. The planting was in hills 42 inches each way for corn, and 42 inches one way by 21 inches the other for potatoes. The planting of both corn and potatoes was done on the same dates at all places. Harrowing after planting before the seed was up and flat cultivation for both crops was adopted, using cultivators with 2.5 to 3 inch shovels.

*Manufacturer's guarantee for this guano was phosphoric acid 8 per cent., ammonia 3 per cent., and potash 2.5 per cent.

To control the Colorado potato beetle hand picking was practiced, beginning with the appearance of the old beetles. In this way little injury was done by them at either locality. It transpired, however, when the tubers were well set, and perhaps one-half grown, that severe "tip-burn" struck the vines at all four places, greatly interfering with and reducing the yields, except at Janesville. At all places except Janesville the vines dried completely before the crop matured.

Relation of Yields to Fertilization.

YIELDS OF CORN.

It was the aim to have the corn cut on each soil type as soon as the ears were fully matured and the stalk at the proper stage for cutting and shocking, with the leaves and husks yet green. The weight of each row was determined as cut from the several sub-plots and the sums taken for the total mean yield under each fertilization for the respective soil types. In the next table are given the comparative green weights of corn as cut, which may be taken to represent somewhat less than the amounts of silage produced.

Comparative green weights of corn.

	Nothing added.	5 tons manure.	10 tons manure.	15 tons manure.	300 lbs. guano.
	In pounds per acre.				
	Four poorer soils.				
Norfolk Sandy Soil	5080.1	8330.4	11766.7	14593.5	8887.5
Selma Silt Loam	8986.8	9580.6	10044.0	10299.9	8445.4
Norfolk Sand	5194.9	7843.2	9297.0	10949.0	6852.4
Sassafras Sandy Loam	5983.2	9248.9	10796.5	10959.4	8175.1
Average	6311.3	8750.8	10476.1	11688.0	8090.1
	Four stronger soils.				
Hagerstown Clay Loam	10762.2	13183.2	14895.3	15224.5	12630.0
Hagerstown Loam	13307.0	13273.1	14576.7	13510.1	14627.5
Janesville Loam	24922.2	25544.5	26228.6	27204.0	24346.8
Miami Loam	17866.8	22467.5	23448.2	25384.0	19518.9
Average	16714.6	18617.1	19787.2	20330.7	17780.8

It will be seen from this table that, with each and every soil type except the Hagerstown Loam, there is a well marked ten-

dency to an increase in yield from the sub-plots to which nothing was added to the ones receiving 15 tons of stable manure. In the case of the Hagerstown Loam, it was found, when the field came to be studied in detail, that there were great physical as well as chemical differences in the area chosen on this type, rendering it unsuited to a comparative study of this kind. There were also shown to be considerable irregularities in the soil conditions of the Sassafras Sandy Loam and in the two Goldsboro types, which could not be entirely eliminated by the repetition adopted of sub-plots, in alternate series.

If these yields are expressed percentagely on the yields of the 15-ton fertilization as a base, taking those as 100, the results stand as indicated below.

Percentage relations of yield under different fertilizations.

	Nothing added. Per cent.	5 tons manure. Per cent.	10-tons manure. Per cent.	15-tons manure. Per cent.	300-lbs. guano. Per cent.
Mean of 4 poorer soils.........	53.98	74.47	89.65	100.00	69.21
Mean of 4 stronger soils.	82.19	91.59	97.34	100.00	87.46
Mean of 8 soils	71.89	85.32	94.50	100.00	80.83

It will be seen that in the case of the poorer soils there is a percentage difference of 46 between the yields from the 15-ton sub-plots and those to which nothing was added; but a difference of only 18 on the stronger soils.

The 5-ton sub-plots have made a relatively greater gain than have the sub-plots to which the 300-lbs. of guano were added.

If the differences in yield are expressed in pounds per acre, using the mean yields on the untreated soils as a basis, the results will stand as next given.

Increase in yield due to fertilization.

	Nothing added.	5-tons manure.	10-tons manure.	15-tons manure.	300-lbs. guano.
	Mean of 4 poorer soils.				
Green weight, lbs. per acre...	6311.3	8750.8	10476.1	11688.0	8090.1
Green weight, nothing added.	6311.3	6311.3	6311.3	6311.3	6311.3
Difference	0000.0	2439.5	4164.8	5376.7	1778.8
	Mean of 4 stronger soils.				
Green weight, lbs. per acre.	16714.6	18617.1	19787.2	20330.7	17780.8
Green weight, nothing added	16714.6	16714.6	16714.6	16714.6	16714.6
Difference	00000.0	1902.5	3072.6	3616.1	1066.2

These results show that, both relatively and absolutely, adding fertilizers to the poorer soils has had a greater effect than the same treatment with stronger soils. The guano added was the same on all soils but the presumption is that the stronger soils received a better quality of manure than the poorer soils did, from which it follows that the fertilizers have had a lower efficiency on the stronger soils.

It was not practicable to determine the per cent. of water in the corn at the time it was cut, as should have been done for strict comparison of yields. It is probable that 33⅓ per cent. of dry matter is too low, but may be taken as a safe estimate. On this basis, the mean yields of dry matter will stand as below.

Estimated increase in yield of dry matter in corn due to fertilization.

	Nothing added.	5-tons manure.	10 tons manure.	15-tons manure.	300 lbs. guano.
	Mean of 4 poorer soils.				
Dry weight, lbs. per acre....	2103.8	2916.9	3492.0	3896.0	2696.7
Dry weight, nothing added...	2103.8	2103.8	2103.8	2103.8	2103.8
Difference	0000.0	813.1	1388.2	1792.2	592.9
	Mean of 4 stronger soils.				
Dry weight, lbs. per acre .. .	5571.5	6205.7	6595.7	6776.9	5926.9
Dry weight, nothing added...	5571.5	5571.5	5571.5	5571.5	5571.5
Difference..............	0000.0	634.2	1024.2	1205.4	355.4

On this basis of comparison the 15-tons of manure have about doubled the gain over the 5-tons per acre, and the 300-lbs. of guano have only made a little more than half the gain the 5-tons of manure per acre made, as an average, on each group of soils.

When the corn was husked, after drying in the shock, a composite sample of the ears was taken for each fertilization, at the time the corn was weighed, and the water-free shelled corn computed from the per cents. of dry matter and of shelled corn found. These results are given in the next table.

Yields of water-free shelled corn from 8 soil types under 5 fertilizations.

	Nothing added. Bu.	5 tons manure. Bu.	10-tons manure. Bu.	15-tons manure. Bu.	300-lbs. guano. Bu.
	Four poorer soils.				
Norfolk Sandy Soil	16.73	26.68	38.55	51.61	29.62
Selma Silt Loam	32.95	34.31	37.32	39.48	30.94
Norfolk Sand	15.80	26.68	29.70	35.62	25.59
Sassafras Sandy Loam	22.02	25.39	31.82	33.40	20.16
Average	21.875	28.265	34.348	40.028	26.578
	Four stronger soils.				
Hagerstown Clay Loam	35.00	42.79	54.12	58.46	47.58
Hagerstown Loam	49.65	49.00	49.51	46.39	51.63
Janesville Loam	70.27	73.18	77.05	68.51	72.92
Miami Loam	50.72	64.47	66.80	73.82	56.11
Average	51.41	57.36	61.87	61.795	57.06

It is here seen that, on the four poorer soils, there is a systematic difference in yield of water-free shelled corn which is closely related to the fertilizers applied to the soil. The group of four stronger soils do not show, throughout, this systematic relation. The reason for the departure, in the Hagerstown Loam, has been stated. There is this to be said regarding the Janesville Loam; the area chosen is part of a well managed dairy farm where the fields are held well up to their maximum limits of productiveness so far as plant food is concerned. Moreover, it was observed, as the corn was coming into full tassel, that in the outside row of hills next to the fallow area, throughout the entire 440 feet, the corn was very materially

shorter than on the balance of the field. Under ordinary conditions this would have been the heaviest corn. Upon making inquiry of the owner, it was learned that in the Spring of the previous year he had applied manure to a strip of land along this side of the field and it was his judgment that the shorter row of corn marked the boundary of that area. The fertilizations made here were at right angles to the line referred to. It is not unreasonable, therefore, to suppose that, for this soil, the adding of 15 tons of manure per acre, to that which had been applied the preceding year, really passed the limit of increasing the yield of corn for this soil under the conditions of this season, which was rather cold and abundantly wet.

The mean increase in yield of shelled corn due to the application of fertilizers is expressed in the next table.

Increase in yield of shelled corn due to fertilization.

	Nothing added. Bu.	5-tons manure. Bu.	10-tons manure. Bu.	15-tons manure. Bu.	300-lbs. guano. Bu.
	Mean of four poorer soils.				
Water-free shelled corn, bu. per acre ..	21.88	28.27	34.35	40.03	26.58
Water-free shelled corn, nothing added	21.88	21.88	21.88	21.88	21.88
Difference	00.00	6.39	12.47	18.15	4.70
	Mean of four stronger soils.				
Water-free shelled corn, bu. per acre ..	51.41	57.36	61.87	61.80	57.06
Water-free shelled corn, nothing added	51.41	51.41	51.41	51.41	51.41
Difference	00.00	5.95	10.46	10.39	5.65

It will be seen, from the data here presented, that, on the four poorer soils, the increase in shelled corn has been nearly proportional to the amounts of manure applied to the soils, and at the mean rate of 69.10 lbs. of water-free kernels per ton of manure used, thus:

	Bu.	Per ton.
Increase with 15 tons manure	18.15	1.210
Increase with 10 tons manure	12.47	1.247
Increase with 5 tons manure	6.39	1.278
Total ...30 tons manure	37.01	
Per ton	1.234 = 69.10 lbs.	

The increase in total dry matter was:

	Lbs.	Per ton.
Increase with 15 tons manure	1792.2	119.48
Increase with 10 tons manure	1388.2	138.82
Increase with 5 tons manure	813.1	162.62
Total ... 30 tons manure	3993.5	
Per ton	133.12	

The increase of yield of dry matter in the form of shelled corn is

$$37.01 \times 56 = 2072.56 \text{ lbs.}$$

This leaves the dry matter in the form of stalks, leaves and cobs

$$3993.50 - 2072.56 = 1920.94 \text{ lbs.}$$

so that the gain here is at the rate of 64.03 lbs. of dry matter per ton of manure applied. It thus appears that the major effect of the stable manure has been in the direction of increasing grain rather than stalk, leaves and cob, the ratio being

69.10 of kernel to 64.03 of stalk, leaves and cob.

It is not an infrequent experience that the addition of potash to soils increases the yield of shelled corn more than it does stalk and foliage. It has been shown, in Bulletin "C", also, that the recovered amounts of potash bore a close relation to the yields of shelled corn from these soils and the relation here pointed out is quite in accord with the view that the larger amounts of soluble potash shown to be present in the soils giving the largest yields has been an influential factor in determining those differences of yield.

At various times during the season photographs were taken of both corn and potatoes on the same date for all of the soil types. Some of these photographs are here reproduced to exactly the same scale, so that they give to the eye a quantitative expression of the differences in growth as the observer would recognize them. There have been reproduced on pages 10, 11, 12 and 13 photographs of corn taken on August 14 at the four stations which represent the appearance of the corn upon four of the soil types where 15 tons of stable manure had been ap-

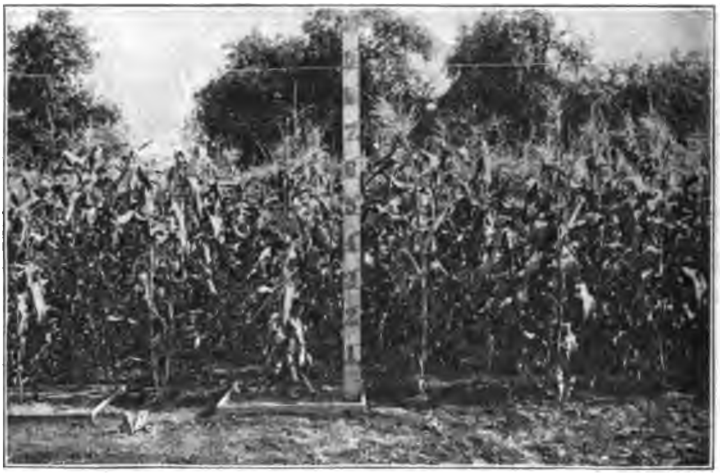

FIG. 2.—Corn where 15 tons manure had been applied per acre to Hagerstown Clay Loam. Line stretched across target is at mean height of corn on the plot. The two small hills in squares have received no water during season and have reached their development on the moisture present in the soil at planting.

FIG. 3.—Corn on Hagerstown Clay Loam to which nothing was added. Corn was planted and photograph taken on same dates as for Fig. 2.

FIG. 4.—Corn on Norfolk Sandy Soil where 15 tons manure had been applied per acre. Corn was planted and photographed on same dates as for Fig. 2.

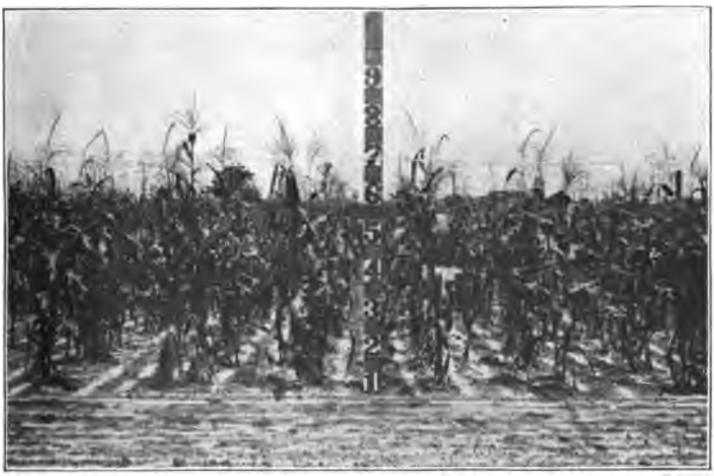

FIG. 5.—Corn on Norfolk Sandy Soil to which nothing had been added. Corn was planted and photographed on same dates as for Fig. 2.

FIG. 6.—Corn on Miami Loam where 15 tons of manure had been applied per acre. Corn was planted and photographed on same dates as for Fig. 2.

FIG. 7.—Corn on Miami Loam to which nothing had been added. Corn was planted and photographed on same dates as for Fig. 2.

FIG. 8.—Corn on Norfolk Sand where 15 tons of manure had been applied per acre. Corn was planted and photographed on same dates as for Fig. 2.

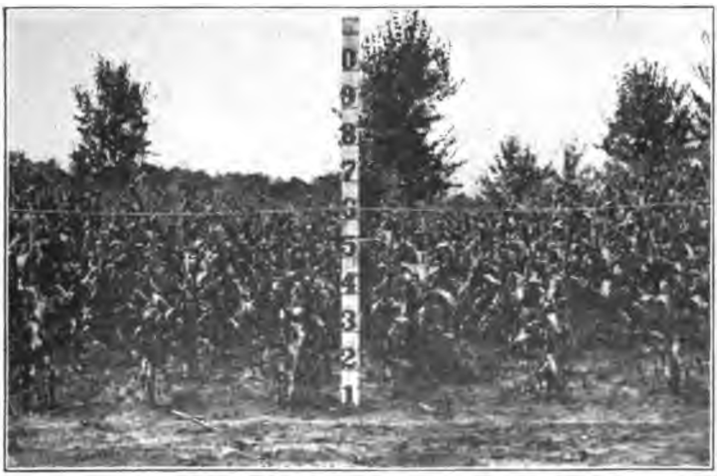

FIG. 9.—Corn on Norfolk Sand to which nothing had been added. Corn was planted and photographed on same dates as for Fig. 2.

different soil types quite as well as did the corn. The results which were secured from the potatoes are given in the next table:

Total yields of potatoes under five fertilizations on 8 soil types.

	Nothing added.	5 tons manure.	10-tons manure.	15-tons manure.	300-lbs. guano.
	In bushels per acre.				
	Four poorer soils.				
Norfolk Sandy Soil...... ...	21.50	38.10	70.90	67.30	40.80
Selma Silt Loam........	57.50	76.00	78.40	72.80	67.20
Norfolk Sand.................	61.46	112.67	132.81	132.62	73.82
Sassafras Sandy Loam	75.42	101.63	101.63	115.10	73.00
Average................	53.97	82.10	95.94	96.96	63.71
	Four stronger soils.				
Hagerstown Clay Loam	132.68	167.74	180.91	206.92	151.78
Hagerstown Loam...........	137.90	159.39	165.95	179.49	142.24
Janesville Loam.............	215.30	280.20	329.90	346.90	282.20
Miami Loam	188.30	237.20	267.30	280.70	211.90
Average......	168.55	211.13	236.02	253.50	197.03

Notwithstanding the disturbing factor of "tip-burn," which has much reduced the yield, there is clearly shown a marked influence upon yield effected through the application of such moderate amounts of manure as have been here used. Even the 5 tons of stable manure has made a clear and even strong increase in yield on each and all of the 8 soil types, whether naturally poor or strong.

Then, too, in the cases of the Janesville Loam and the Hagerstown Loam, where there were not wholly concordant results with corn, the differential effect of the varying amounts of manure are clearly defined by the yields. The soil was more uniform at Lancaster on that portion of the Hagerstown Loam occupied by the potatoes than was that occupied by the corn, and the area at Janesville, where the potatoes were planted, had not been manured the previous year, as had been the case with that occupied by the corn, as already explained.

The increase of potatoes associated with the different amounts of manure applied, and with the guano, appear in the next table.

Increase in yield of potatoes due to manure and guano.

	Nothing added. Bu.	5 tons manure. Bu.	10-tons manure. Bu.	15-tons manure. Bu.	300-lbs guano. Bu.
	From four poorer soils.				
Mean yield per acre......	53.97	82.10	95.94	96.96	63.71
Mean yield, nothing added...	53.97	53.97	53.97	53.97	53.97
Difference..............	00.00	28.13	41.97	42.99	9.74
	From four stronger soils.				
Mean yield per acre...........	168.55	211.13	236.02	253.50	197.03
Mean yield nothing added....	168.55	168.55	168.55	168.55	168.55
Difference..............	000.00	42.58	67.47	84.95	28.48

The increase in yield of potatoes associated with the manure, in bushels per ton, has been:

	On poorer soils.		On stronger soils.	
	Total. Bu.	Per ton. Bu.	Total. Bu.	Per ton. Bu.
With 5 tons manure.....................	28.13	5.626	42.58	8.516
With 10 tons manure.....................	41.97	4.197	67.47	6.747
With 15 tons manure.....................	42.99	2.866	84.95	5.663
Total 30 tons manure.....................	113.09		195.00	
Average per ton.....................	3.77		6.50	

The comparatively small effect of the manure on yields on the four poorer soils must be ascribed, in part, to the more intense development of "tip-burn" on these soils.

Taking the amount of water in potatoes at 78.9 per cent., the mean increase of dry matter, per ton of manure, was, on the four poorer soils, 47.73 lbs. and on the four stronger soils 82.29 lbs.

No observations were made which make it possible to state the amounts of dry matter produced in the potato vines on the different soil types; but on August 16 four typical hills were selected, one from each of the four sub-plots on each soil type to which 15 tons of manure had been added, and the air-dry weights of these vines was determined, from which the yields of air-dry matter in vines, computed in pounds per acre, were found to be as given in the next table.

Air-dry weights of potato vines on the 15-ton sub-plots.

Norfolk Sandy Soil	Selma Silt Loam.	Norfolk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam	Hagerstown Loam.	Janesville Loam.	Miami Loam.
In pounds per acre.							
943	1014	853	1021	1959	1931	8112	5779

The mean height of potato vines on the different sub-plots was measured weekly at all stations, and in the next table there are given the values recorded on July 20.

Mean height of potato vines on July 20.

	Nothing added. Inches.	5 tons manure. Inches.	10-tons manure. Inches.	15-tons manure. Inches.	300-lbs. guano. Inches.
---	Four poorer soils.				
Norfolk Sandy Soil	19.5	20.0	23.5	24.5	24.5
Selma Silt Loam	23.0	22.5	23.0	24.0	24.5
Norfolk Sand	16.0	21.0	23.0	28.0	19.0
Sassafras Sandy Loam	18.0	21.0	24.0	26.0	19.0
	Four stronger soils.				
Hagerstown Clay Loam	27.0	29.0	30.0	31.0	28.0
Hagerstown Loam	22.0	24.5	24.0	25.0	22.0
Janesville Loam	19.3	26.5	28.3	29.7	19.8
Miami Loam	23.5	24.3	25.7	25.3	24.5

At this time, it will be seen, no very marked difference had developed between the vines at the four stations, although the influence of fertilization was making itself felt. There is, however, so much difference in the extent of branching of the vines that height alone, after branching begins, conveys no definite idea of the amount of vine which has developed. At Janesville the vines came to completely cover the ground and they did to a large extent at Lancaster; but this did not occur on either of the poorer soils.

MEAN INCREASES IN YIELDS ON 8 SOIL TYPES DUE TO FERTILIZATION.

If the yields of both corn and potatoes from the eight soil types are brought together under the five fertilizations, the results will appear as next given:

Mean increase in yields on 8 soil types due to differences in fertilization with stable manure.

	Yields of Corn.				Yields of Potatoes.			
	On four poorer soils.		On four stronger soils.		On four poorer soils.		On four stronger soils.	
	Total. Bu.	Per ton Bu.	Total. Bu.	Per ton Bu.	Total. Bu.	Per ton Bu.	Total. Bu.	Per ton Bu.
With 5 tons manure..	6.39	1.278	5.95	1.190	28.13	5.626	42.58	8.516
With 10 tons manure..	12.47	1.247	10.46	1.046	41.97	4.197	67.47	6.747
With 15 tons manure..	18.15	1.210	10.39	.693	42.99	2.866	84.95	5.663
Total 30 tons manure..	37.01		26.80		113.09		195.00	
Mean per ton..........	1.234		.893		3.77		6.50	
Mean per ton as dry matter.....	69.104 lbs.		50.008 lbs.		47.73 lbs.		82.29 lbs.	
Mean per ton as dry matter from 8 soils			59.556 lbs.				65.01 lbs.	
Mean per ton as dry matter of 2 crops and 8 soils 62.283 lbs.								
Mean per ton as dry matter of 2 crops from poorer soils					58.417 lbs.			
Mean per ton as dry matter of 2 crops from stronger soils							66.149 lbs.	

(1) It appears from this table, as an average of all trials on 8 soils with corn and potatoes, that 1 ton of stable manure has increased the yield at the mean rate of 62.283 lbs. of dry matter in the form of grain and tubers alone. If the dry matter in stalks and vines were included, the increase would not be far from 100 lbs. per ton.

(2) The relative increase of dry matter, in the form of grain and tubers, has been in the ratio of 59.56 for corn to 65.01 lbs. for potatoes, taking the dry matter in the potatoes at 21.1 per cent., and 60 pounds per bushel as the weight for potatoes and 56 pounds per bushel for corn.

(3) The average increase on the four poorer soils, as compared with that on the four stronger soils, has been as 58.417 to 66.149, the increase being greater on the stronger soils; but, as has been pointed out, the true relation is probably the reverse, as it was with the corn. The "tip-burn" on the potatoes grown on the four poorer soils did have a relatively greater effect in reducing the yield there.

(4) The mean increase in dry matter per ton of manure as grain and tubers alone, where 5 tons were applied, was at the

rate of 79.311 lbs. per ton; for 10 tons the increase was 66.740 lbs. per ton; and for 15 tons it was at the rate of 53.636 lbs. per ton. There has, therefore, been a relatively higher efficiency where the smaller amounts of manure were added.

Influence of Farm Yard Manure on the Water-Soluble Salts of Soils.

There is given in Bulletin "C,"* p. 81, a tabular statement of the amounts of water-soluble salts recovered from 8 soil types, as an average of determinations made on 6 different dates, together with the differences between the total salts recovered from each of the fertilized sub-plots and from the sub-plots not fertilized. There is presented here a statement of the influence of the stable manure upon the amounts of each ingredient recovered from the soil under field conditions.

EFFECT OF 5, 10, AND 15 TONS OF MANURE UPON THE WATER-SOLUBLE SALTS OF FIELD SOILS.

The observations here presented cover a study, under field conditions, from the time of applying the stable manure to the soil the last of April until near the end of June, a period of about 60 days, during which time samples were collected on six dates. The manure had been very carefully and uniformly spread over the surface of the fields and was plowed under to a depth of 6 to 8 inches. The soil samples, in all cases, were composites of four cores, one from each of the four repeated sub-plots, and extended through the entire surface foot.

In the next table there are given the percentage differences in the amounts of each ingredient determined, using the amounts recovered from the unmanured soil as bases and calling these 100.

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*Bureau of Soils. "C," Relation of Crop Yields to the Amounts of Water-soluble Plant Food Materials. Recovered from Soils.

Percentage relations of water-soluble salts recovered from soils receiving 5, 10, and 15 tons of stable manure per acre.

	Nothing added. Per cent.	5-tons manure. Per cent.	10-tons manure. Per cent.	15-tons manure. Per cent.	300-lbs. guano. Per cent.
Yields of dry matter in grain and tubers	100.00	122.4	138.5	146.5	115.4
Amounts of K recovered	100.00	109.5	115.2	123.7	105.3
Amounts of Ca recovered	100.00	100.1	102.1	107.2	117.3
Amounts of Mg recovered	100.00	103.1	110.1	113.0	112.3
Amounts of NO_3 recovered	100.00	106.3	104.6	111.5	104.3
Amounts of HPO_4 recovered	100.00	105.4	114.7	107.4	98.5
Amounts of SO_4 recovered	100.00	100.8	101.5	108.4	126.9
Amounts of HCO_3 recovered	100.00	118.3	129.8	130.4	139.1
Amounts of Cl recovered	100.00	82.1	108.0	164.0	126.8
Amounts of SiO_3 recovered	100.00	118.2	129.7	130.4	139.1
Amounts of total salts recovered	100.00	103.9	107.2	111.3	119.3

From this table it is very clear that the effect of the different amounts of stable manure, applied to these soils, and that of the 300-lbs. of guano, as well, has been such, upon the recoverable water-soluble salts, as to enable the same treatment to remove different amounts from each fertilization.

As a rule, the amounts increase with the amounts of manure added, but how these amounts are related to the amounts carried to the soils with the manure cannot be shown, because altered plans have prevented the analyses of the manure and guano used, as had been the intention. There is a clear quantitative relation, too, between the yields and the salts recovered, these increasing where the essential ingredients of plant food are higher.

Two of these soils, the Miami Loam and the Norfolk Sand, were subjected to repeated washing with alternate drying between each washing, using samples from the sub-plots to which no manure had been added and from those to which 15 tons had been applied. The results which were secured by this treatment are given in the next table.

Amounts of salts recovered from manured and unmanured soils by washing 11 times in distilled water.

	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million of dry soil.								
	Miami Loam.								
15 tons manure ...	211.12	628.00	220.18	57.24	397.40	521.00	571.00	0.00	336.80
Nothing added...	190.84	597.50	211.12	62.42	382.00	528.50	579.00	0.00	338.60
Difference	20.28	30.50	9.06	−5.18	15.40	−7.50	−8.00	0.00	−1.80
	Norfolk Sand.								
15 tons manure ...	155.44	113.00	80.44	25.89	86.76	191.00	260.00	2.00	141.20
Nothing added ...	126.12	101.00	74.55	19.10	85.56	163.00	306.00	2.00	140.00
Difference	29.32	12.00	5.89	6.79	1.20	28.00	−46.00	0.00	1.20

From this table it is seen that, so far as the three bases are concerned, materially larger amounts of each have been recovered from the manured soils than were recovered from those not manured, under exactly the same treatment. It must be held in mind that the bases have been demonstrated to be absorbed more by soils than the negative radicles are; and further, that the application of stable manure does bring into play the absorption forces whose tendency is to liberate certain ingredients from soils while others are fixed. Notwithstanding the tendencies to absorption, it is shown that *under the conditions of the treatment* more potash, lime, magnesia and phosphoric acid have been recovered from the soils to which they were added as carried by the stable manure.

Moreover, while it must be conceded that the cooking to which these soils were, in a measure, subjected, during the drying, may have rendered potash, lime, magnesia and phosphoric acid soluble from the manure when it would not otherwise have been so, it is yet clear that, if rendered soluble, it was not again fixed by the soils, although in contact with them, to such an extent but that more was recovered from the manured than from the unmanured soils.

The excess amount of potash dissolved from the two manured soils was at the rate of 62.47 lbs. per acre from the Miami Loam and 105.1 lbs. from the Norfolk Sand. If the potash is really left in a more soluble form in the Norfolk Sand

than it is in the Miami Loam, and if this more soluble potash has been an influential factor in determining the yield of corn, this relation is in harmony with what has been observed, namely, that like amounts of manure were relatively more effective on the poorer soils which have been shown to have a less strong absorptive power for the potash.

INFLUENCE OF 25, 50, 100 AND 200 TONS OF MANURE PER ACRE UPON THE WATER-SOLUBLE SALTS OF SOILS.

In order to supplement the field studies regarding the influence of small amounts of stable manure upon the water-soluble salts in soils, a series of experiments was started the first week in July to measure the influence of 25, 50, 100 and 200 tons of manure per acre upon the water-soluble salts which could be recovered from the 8 soil types under investigation.

The farm yard manure used was cow dung, taken from the yard not more than two or three days after being dropped. It was rendered water-free by drying at 100° C. and then ground to a fine powder by running through a mill. From the water-free manure the requisite amounts were weighed out at the central laboratory, and sent in separate parcels to the field parties in proper amounts to be incorporated with designated amounts of soil. Like amounts of the same manure were, therefore, used on all soils.

The 20 lbs. of soil used were composites taken with the soil tube from the surface foot of the unfertilized sub-plots of the respective soil types. Where the soils were not in their optimum moisture condition when collected, they were rendered so by the addition of water.

After having been thoroughly mixed, the soil was weighed out in 4-lb. lots and with these the prepared manure was thoroughly incorporated in the following amounts.

Amounts of water-free manure added to 4-pound lots of soil.

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
0 Grams.	14.18 Grams.	28.35 Grams.	56.7 Grams.	113.4 Grams.

In this condition the moist soils were transferred to 2-quart Mason fruit jars, the mouths of which were closed, with a plug of loose cotton wool, to check evaporation but permit normal aeration. The jars were then weighed and set aside. Once each week, after starting the experiment, the plugs of cotton wool were removed, the jars covered, inverted and shaken to secure a thorough exchange of air throughout the entire volume of soil.

Considering the weight of the moist soil for each soil type to be 4,000,000 lbs. per acre-foot and the manure to carry 70 per cent. of water, the amounts added, supposing them to be incorporated with the surface 6 inches of soil only, were at the rates of 25.22, 50.43, 100.87 and 201.73 tons per acre.

A partial gravimetric analysis of the manure used, made by Dr. Schreiner, gave the results stated in the table.

Composition of manure used.

No. of sample.	Ash.	Insoluble in HCl, sand, etc	Soluble in HCl.	Potash as		Lime as		Magnesia as		Phosphoric acid as	
				K.	K_2O.	Ca.	CaO.	Mg.	MgO	HPO_4.	P_2O_5.
In per cent. of the dry manure.											
2	....	9.568	....	.7254	.8788	1.3266	1.8565	.5803	.9627	....	....
4	16.180	9.060	7.120	......	....	......	......	.....	.....	2.2639	1.6744

The Mason jars with their soil content were weighed from time to time during the interval of the experiment and enough water added to restore that lost by evaporation, and on September 10 and 11 the samples were examined for the water-soluble salts which could be recovered from them by single washings during three minutes. The results obtained are given in the following sections.

POTASH ABSORBED FROM MANURE BY 8 SOILS.

Influence of different amounts of stable manure upon the water-soluble potash recovered with distilled water.

	Norf'lk Sandy Soil.	Selma Silt Loam.	Norf'lk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hag-erst'wn Loam.	Janesville Loam.	Miami Loam.
	In parts per million of dry soil.							
25.22 tons manure...	21.20	21.20	20.00	15.60	21.20	25.60	19.40	18.08
Nothing added......	11.60	14.12	11.92	9.56	11.48	20.30	19.12	16.28
Difference.......	9.60	7.08	8.08	6.04	9.72	5.30	.28	1.80
50.43 tons manure...	29.60	24.40	26.00	33.40	28.40	39.40	23.90	22.16
Nothing added......	11.60	14.12	11.92	9.56	11.48	20.30	19.12	16.28
Difference.......	18.00	10.28	14.08	23.84	16.92	19.10	4.78	5.88
100.87 tons manure..	65.00	50.80	56.80	56.00	54.10	42.10	28.40	23.60
Nothing added......	11.60	14.12	11.92	9.56	11.48	20.30	19.12	16.28
Difference.......	53.40	36.68	44.88	46.44	42.62	21.80	9.28	7.32
201.73 tons manure..	143.60	106.00	116.20	119.20	104.00	108.40	68.60	62.60
Nothing added......	11.60	14.12	11.92	9.56	11.48	20.30	19.12	16.28
Difference.......	132.00	101.88	104.28	109.64	92.52	88.10	49.48	46.32

The data of this table show, in a striking manner, that there is a profound difference in the capacities of these 8 soils to hold back potash from solution by the first 3-minute washing, when applied to them in the form of fresh cow manure and left in contact, under like conditions, during 65 days, between July 1 and September 11. The differences between the soils are more clearly brought out by the diagram, Fig. 12, p. 26.

The curve of 100-tons per acre shows a strong difference between the Hagerstown Loam and the two Janesville soils and the other five members of the series. The application of 200-tons of manure per acre places the two Janesville soils in one group, the two Lancaster soils in another, and leaves the Norfolk Sandy Soil alone as having the smallest capacity for holding back potash. This relation was also found when liquid manure was applied, as cited in Bulletin "D," page 114.

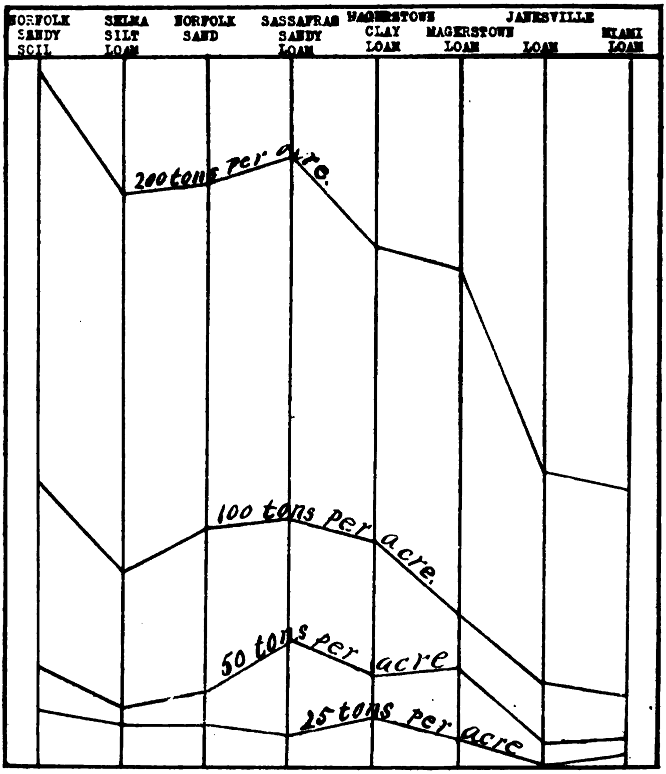

FIG. 12.—Showing relative amounts of potash recovered from 8 soil types 65 days after the application of different amounts of manure.

INFLUENCE OF MANURE ON WATER-SOLUBLE LIME IN 8 SOILS.

In the next table there have been brought together the results of the determinations for lime, made on the same soil extracts as those for potash and at the same time.

In these cases, as with the potash, more lime has been recovered from each soil after having had an application of manure, and this is in accord with the observations made under field conditions where 5, 10 and 15 tons of manure had been applied. Contrary to what was observed with the potash, more, rather than strongly less, lime has gone into solution from the Lancaster and Janesville soils. According to the view held in 1865 and earlier, the absorption of potash by these soils has

"forced the lime into solution." It must, however, be said that the same soils which have absorbed least lime are the ones which observation has abundantly proved contain most lime in water-soluble form.

Influence of different amounts of stable manure upon the quantity of water-soluble lime recovered with distilled water.

	Norf'lk Sandy Soil.	Selma Silt Loam	Norf'lk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hag-erst'wn Loam.	Janesville Loam	Miami Loam.
	In parts per million of dry soil.							
25.22 tons manure...	65.00	56.00	45.00	52.00	86.00	105.00	91.25	72.50
Nothing added......	29.50	54.00	34.00	46.00	78.75	92.00	82.00	68.75
Difference	35.50	2.00	11.00	6.00	7.25	13.00	9.25	3.75
50.43 tons manure...	45.00	59.00	51.00	57.00	102.50	112.50	107.50	90.00
Nothing added......	29.50	54.00	34.00	46.00	78.75	92.00	82.00	68.75
Difference	15.50	5.00	17.00	11.00	23.75	20.50	25.50	21.25
100.87 tons manure..	56.25	70.00	65.00	76.25	130.00	125.00	125.00	112.50
Nothing added......	29.50	54.00	34.00	46.00	78.75	92.00	82.00	68.75
Difference.	26.75	16.00	31.00	30.25	51.25	33.00	43.00	43.75
201.73 tons manure..	83.75	93.75	78.75	91.25	150.00	140.00	162.50	145.00
Nothing added......	29.50	54.00	34.00	46.00	78.75	92.00	82.00	68.75
Difference	54.25	39.75	44.75	45.25	71.25	48.00	80.50	76.25

INFLUENCE OF MANURE ON THE WATER-SOLUBLE MAGNESIA IN 8 SOILS.

When the results for the magnesia are brought together they stand as given in the next table.

In the case of the magnesia it will be observed that the influence of the manure upon the amounts dissolved has taken an intermediate position between that exerted upon the potash and upon the lime. As was the case with the potash, less has been recovered and, therefore, more absorbed by the four stronger soils; but the differences between the members of the two groups of soils are not nearly so strongly marked. In the case of the Janesville Loam, the manure had the effect of reducing the quantity of magnesia below the amount recovered from the untreated soil, unless it happened that in some way the amount determined for the unmanured soil is too high.

This does not appear probable, in view of the general fact that, for all soils, the manure can scarcely be said to have increased the amounts of magnesia recovered until the soils to which 100 tons per acre had been applied are reached.

Influence of different amounts of stable manure upon the water-soluble magnesia recovered with distilled water.

	Nor-fork Sandy Soil.	Selma Silt Loam.	Nor-fork Sand.	Sassa-fras Sandy Loam.	Hagers-town Clay Loam.	Hagers town Loam.	Janes-ville loam.	Miami Loam.
	In parts per million of dry soil.							
25.22 tons manure...	8.78	8.78	9.64	8.68	26.71	23.14	23.46	17.64
Nothing added......	7.61	7.40	9.78	8.56	27.17	22.82	28.06	18.40
Difference.......	1.17	1.38	—.14	—.12	—.46	.32	-4.60	—.76
50.43 tons manure...	9.65	7.40	16.30	14.89	31.71	28.52	24.82	23.46
Nothing added......	7.61	7.40	9.78	8.56	27.17	22.82	28.06	18.40
Difference......	2.04	0.00	6.52	6.33	4.54	5.70	-3.24	5.06
100.87 tons manure..	36.57	31.84	33.58	27.61	57.04	41.78	35.68	35.68
Nothing added......	7.61	7.40	9.78	8.56	27.17	22.82	28.06	18.40
Difference.......	28.96	24.44	23.80	19.05	29.87	18.96	7.62	17.28
201.73 tons manure.	50.34	57.04	60.16	61.14	68.48	61.14	64.72	57.04
Nothing added....	7.61	7.40	9.78	8.56	27.17	22.82	28.06	17.40
Difference.....	42.73	49.64	50.38	52.58	41.31	38.32	36.66	38.64

The mean differences of magnesia, as shown for the soils receiving the 200 tons of manure, stand in the relations of 100 for the Southern soils to 79.31 for the Northern.

INFLUENCE OF 5, 10 AND 15 TONS OF STABLE MANURE ON THE AMOUNTS OF NITRIC ACID IN SOILS.

It was found in the comparative study of nitrates in field soils at various times during the season, that not infrequently less rather than more nitrates were recovered from the soils to which most manure had been applied. In the next table there are brought together the observed amounts of nitrates in the surface foot of the different soil types receiving different fertilizations.

Amounts of nitric acid (NO_3) in field soils receiving different amounts of manure.

	Nothing added.	5-tons manure.	10-tons manure.	15-tons manure.	300 lbs. guano	Nothing added.	5-tons manure	10-tons manure.	15-tons manure.	300 lbs. guano
	In parts per million of dry soil.									
	Goldsboro, North Carolina.									
	Norfolk Sandy Soil.					Selma Silt Loam.				
April 29	5.26	6.37	6.92	10.38	4.04	3.78	2.42	5.76	3.66	1.82
May 18	14.52	24.22	18.16	21.36	16.52	20.18	16.52	16.52	22.70	13.46
May 25	15.80	12.52	19.12	25.94	18.16	22.70	21.36	22.70	33.02	13.96
June 1	9.32	18.16	21.36	72.64	22.70	21.36	30.28	36.32	19.12	20.18
June 8	22.70	24.22	40.40	40.40	20.18	10.08	12.10	36.32	30.28	22.70
June 24	16.52	27.94	27.94	40.40	27.94	27.94	30.28	33.02	33.02	24.20
Average	14.02	18.90	22.32	35.19	18.26	17.67	18.49	25.11	23.63	16.05
	Upper Marlboro, Maryland.									
	Norfolk Sand.					Sassafras Sandy Loam.				
April 29	3.16	4.78	4.44	3.64	2.50	6.10	6.06	4.98	5.82	5.54
May 18	8.86	8.96	11.18	10.38	8.14	9.44	13.46	11.18	14.24	10.24
May 25	8.26	10.08	11.36	13.20	11.36	19.12	21.04	25.48	25.96	23.84
June 1	16.16	19.36	17.72	19.92	12.56	14.52	18.40	18.64	19.12	19.64
June 8	19.64	20.76	26.92	26.92	14.84	14.28	20.16	22.36	29.48	16.12
June 24	12.88	9.52	10.32	13.20	8.44	24.20	30.28	23.44	29.64	22.72
Average	11.49	12.24	13.66	14.54	9.64	14.61	18.23	17.68	20.71	16.35
	Lancaster, Pennsylvania.									
	Hagerstown Clay Loam.					Hagerstown Loam.				
April 29	11.54	10.08	11.00	9.08	6.80	11.54	10.08	11.00	9.08	6.80
May 18	11.72	9.96	11.00	26.90	26.90	22.70	20.76	14.52	16.90	24.22
May 25	18.16	25.06	36.32	23.44	39.90	42.80	40.40	45.40	45.40	27.94
June 1	33.02	22.70	17.30	13.20	10.18	36.32	40.40	9.44	7.14	8.08
June 8	29.06	40.40	49.10	38.60	61.60	45.40	68.50	69.80	67.30	30.50
June 24	33.02	46.00	40.40	66.00	117.20	90.80	84.40	80.80	68.60	74.20
Average	22.75	25.70	27.52	29.54	43.76	41.59	44.09	38.49	35.73	28.62
	Janesville, Wisconsin.									
	Janesville Loam.					Miami Loam.				
April 29	36.32	28.56	34.56	32.64	25.96	19.12	5.96	11.00	14.84	9.84
May 18	45.44	55.84	48.40	53.84	52.80	41.30	35.60	43.30	27.10	30.30
May 25	61.60	64.90	58.60	44.80	72.10	86.50	61.60	67.30	59.60	58.60
June 1	74.10	98.20	69.80	64.90	86.50	55.90	58.60	18.16	37.28	51.20
June 8	45.40	55.90	66.00	100.90	88.60	56.80	38.60	42.70	31.30	26.00
June 24	88.60	90.80	79.00	82.60	95.60	53.84	64.90	55.00	52.60	62.60
Average	58.58	65.70	55.39	63.28	70.59	52.24	44.21	39.58	37.12	39.75

From this table it will be seen that there has been no clearly and strongly marked tendency for all the manured soils to show more nitrates than the same soils otherwise treated. The mean values for all soils stand as given in the next table.

Mean observed amount of nitrates in soils to which was added

	Nothing.	Manure.	Guano.
	Eight soil types.		
In parts per million of dry soil	29.21	31.30	30.38
Percentage relation	100.00	107.50	104.00

If, however, the soils are classed, as has before been done, into the poorer and stronger groups and a comparison of the nitrification made, the results will stand as given in the next table.

Relation of nitrification to fertilization.

	Nothing added.	5-tons manure.	10-tons manure.	15-tons manure.	300-lbs. guano.
	Four poorer soils.				
In parts per million of dry soil	15.20	16.97	19.69	23.52	15.08
Percentage relation	100.00	111.60	129.40	154.70	99.20
	Four stronger soils.				
In parts per million of dry soil	43.79	44.93	40.25	41.42	45.68
Percentage relation	100.00	102.40	91.90	94.60	104.30

From this comparison it appears that the addition of manure to the four poorer soils has augmented the development of nitrates and in amounts increasing with the manure added. The guano, however, appears to have had a depressing effect. In the case of the four stronger soils, the two larger amounts of manure added appear to have retarded the accumulation of nitrates in the soil; while the guano may have increased the amount. The two groups of soils, therefore, hold opposite relations as regards the influence the manure has had upon their nitrate content. Such relations as these have been many times noted by different observers and it is unfortunate that it has not yet been clearly demonstrated to what causes such relations should be ascribed.

It is worthy of special remark that notwithstanding the greater effect of the manure in increasing the nitric acid content measured in the four poorer soils, there is, nevertheless, a greater difference as regards nitrates between these two groups

of soil than the different amounts of manure have made within the poorer group. The four stronger soils stand higher above the poorer in nitric acid than 15 tons of manure has been able to increase the nitrates in the poorer soils.

INFLUENCE OF LARGE AMOUNTS OF MANURE UPON NITRIC ACID IN SOILS.

In the experiments with 25, 50, 100 and 200 tons of manure per acre on these same 8 soil types additional light is thrown upon the important problem of nitrification in soils.

In the next table are given the results found in that investigation as regards the amounts of NO_3 which could be recovered from the 8 soils.

Influence of different amounts of manure on the nitric acid content of soil.

	Norf'lk Sandy Soil.	Selma Silt Loam.	Norf'lk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hag-erst'wn Loam.	Janesville Loam.	Miami Loam.
	In parts per million of dry soil.							
Nothing added......	70.00	88.60	71.40	121.00	168.80	161.80	177.20	142.80
25.22 tons manure..	4.32	10.68	24.24	11.72	98.20	77.20	70.00	38.24
50.43 tons manure..	2.27	2.42	3.38	3.37	95.60	35.70	4.54	5.68
100.87 tons manure..	31.60	2.34	5.01	2.75	165.20	39.50	3.50	3.30
201.73 tons manure..	5.78	2.34	4.84	4.04	3.30	3.50	3.86	3.86

Notwithstanding the fact that the five samples for each soil type were identical, that is, taken from the same bulk lot, and had been placed, during 65 days, under entirely similar conditions, there came to be a profound difference in the amounts of nitric acid which were recovered from them, and apparently as the result of adding the manure to the soils.

A strong nitrification had occurred in each and every soil to which no manure was added; it is therefore clear that, so far as environment was concerned, conditions were favorable for nitrification to go forward.

The addition of the manure has certainly interfered with the amounts of nitrates recovered from these soils; and it is certain that denitrification (or else absorption) has taken place in all of the soils to which the largest amount of manure was

added, because there was present in them, when the manure was added, not less than the amounts indicated in them under "Nothing added" on June 24, as given in the table, p. 29. How large this denitrification may have been cannot be stated. It will be seen that in the sample of the Hagerstown Clay Loam to which the next to the largest amount of manure was added, nitrification had exceeded denitrification by an amount nearly equal to the nitrification which took place in the unmanured soil.

The large amounts of manure here used were chosen in order to cover the outside limits of both intentional and accidental practice, and the matter is discussed further in another part of this bulletin.

INFLUENCE OF MANURE UPON THE WATER-SOLUBLE PHOSPHATES IN SOILS.

The amounts of phosphates which were recovered from these 8 soils, after having been 65 days in contact with different amounts of manure, are given in the next table.

Amounts of phosphoric acid recovered from soils treated with manure.

	Norf'lk Sandy Soil.	Selma Silt Loam	Norf'lk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hag-erst'wn Loam	Janesville Loam.	Miami Loam.
	In parts per million of dry soil.							
25.22 tons manure...	2.2	2.8	4.8	16.4	6.4	3.6	3.6	21.2
Nothing added	2.8	1.2	2.4	6.0	7.1	6.1	17.8	2.4
Difference	—.6	1.6	2.4	10.4	—.7	—2.5	-14.2	18.8
50.43 tons manure...	16.2	14.6	29.6	15.6	15.6	13.8	17.2	10.8
Nothing added	2.8	1.2	2.4	6.0	7.1	6.1	17.8	2.4
Difference	13.4	13.4	27.2	9.6	8.5	7.7	—.6	8.4
100.87 tons manure..	21.8	36.7	59.9	35.2	23.9	19.7	31.8	36.4
Nothing added	2.8	1.2	2.4	6.0	7.1	6.1	17.8	2.4
Difference	19.0	35.5	57.5	29.2	16.8	13.6	14.0	34.0
201.73 tons manure..	90.7	115.2	149.0	86.6	61.2	52.2	89.0	126.0
Nothing added	2.8	1.2	2.4	6.0	7.1	6.1	17.8	2.4
Difference	87.9	114.0	146.6	80.6	54.1	46.1	71.2	123.6

Except in the case of the Janesville Loam, the observations show a remarkably small amount of phosphoric acid recovered from the unmanured soils, lower than is normal to the field conditions, and in view of other data in the table it appears not improbable that the determination for the Janesville Loam may be too high.

It is clear that there is a general tendency for the amounts of phosphates which may be removed from the soil with water after a contact of 65 days to increase with the amounts of manure added, but the data are too irregular to justify much more being said. On the whole, more has been recovered from the four poorer soils and, therefore, less has been absorbed, than from the four stronger ones, except where 25 tons of manure were added. The next table shows the relations.

Mean amounts of phosphates recovered from

	Four poorer soils.	Four stronger soils.
	In parts per million.	
Nothing added	3.1	8.2
25 tons manure	6.6	8.7
50 tons manure	19.0	14.4
100 tons manure	38.4	28.0
200 tons manure	110.4	82.1

The amounts of phosphoric acid recovered from the soils receiving the heaviest dressings are of the same order of value as that recovered from the soil from a set of greenhouse benches, where a still heavier dressing of manure had been applied, "3 barrels of soil to one barrel of manure." In this case the benches were fitted early in May and had matured a heavy crop of chrysanthemums when the soil was examined on November 1, yielding, at that time, 105 parts per million of dry soil of HPO_4.

3

INFLUENCE OF FARM YARD MANURE UPON THE AMOUNTS OF WATER-SOLUBLE SULPHATES IN SOIL.

The next table shows the amounts of SO_4 which were recovered from the 8 soil types after having been in contact with about 25, 50, 100 and 200 tons of manure per acre during 65 days.

Amounts of sulphates, as SO_4, recovered from soils treated with different amounts of manure.

	Norfolk Sandy Soil.	Selma Silt Loam.	Norfolk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hagerstown Loam.	Janesville Loam	Miami Loam.
	In parts per million of dry soil.							
25.22 tons manure ...	62	90	63	65	73	112	112	100
Nothing added.	27	50	24	39	59	104	84	73
Difference	35	40	39	26	14	8	28	27
50.43 tons manure...	88	114	65	69	88	132	126	112
Nothing added	27	50	24	39	59	104	84	73
Difference	61	64	41	30	29	28	42	39
100.87 tons manure..	106	150	98	112	142	164	152	136
Nothing added......	27	50	24	39	59	104	84	73
Difference	79	100	74	73	83	60	68	63
201.73 tons manure..	140	192	120	137	168	220	192	164
Nothing added......	27	50	24	39	59	104	84	73
Difference........	113	142	96	98	109	116	108	91

Here, as in the other cases presented, the sulphates recovered with distilled water increase with the amounts of manure added, the mean relations standing for the two groups of soils as next given.

Mean amounts of sulphates, as SO_4, recovered from

	Four poorer soils.	Four stronger soils.
	In parts per million	
Nothing added..	35.0	80.0
25 tons manure..	70.0	99.3
50 tons manure..	84.0	114.5
100 tons manure..	116.5	148.5
200 tons manure..	147.3	186.0

Contrary to what has occurred with the phosphates, but in line with what was true of the lime, the four poorer soils have yielded less sulphates than the stronger soils and, therefore, have absorbed more from the manure, or have rendered it less soluble.

INFLUENCE OF MANURE UPON THE AMOUNTS OF WATER-SOLUBLE BICARBONATES, CHLORINE AND SILICA IN SOILS.

There are brought together in the next table the amounts of HCO_3, Cl and SiO_2 which were recovered from the soils to which these large amounts of fresh manure had been added.

Amounts of bicarbonates, chlorides and silica recovered from soils treated with different amounts of manure.

		Norfolk Sandy Soil.	Selma Silt Loam.	Norfolk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hagerstown Loam.	Janesville Loam.	Miami Loam.
		In parts per million of dry soil.							
Nothing added.....	HCO_3	14	12	14	12	54	40	20	38
25.22 tons manure.	HCO_3	14	16	28	36	80	70	26	44
50.43 tons manure.	HCO_3	22	22	44	46	104	70	46	66
100.87 tons manure.	HCO_3	46	32	76	80	132	126	70	66
201.73 tons manure.	HCO_3	84	64	146	115	225	170	110	135
Nothing added.....	Cl.	2	2	4	2	2	2	2	2
25.22 tons manure.	Cl.	26	30	26	30	30	30	28	28
50.43 tons manure.	Cl.	52	52	54	50	52	62	52	52
100.87 tons manure.	Cl.	102	98	106	100	106	108	104	102
201.73 tons manure.	Cl.	190	198	200	195	210	210	225	205
Nothing added.....	SiO_2	6.8	9.6	9.9	11.5	24.9	26.6	36.2	37.7
25.22 tons manure.	SiO_2	8.4	11.0	8.5	10.6	26.3	31.0	41.5	28.2
50.43 tons manure.	SiO_2	5.9	9.3	4.7	10.1	25.6	24.6	42.0	38.2
100.87 tons manure.	SiO_2	15.2	15.3	6.6	18.0	28.8	27.5	41.9	41.9
201.73 tons manure.	SiO_2	14.4	13.7	14.1	27.5	34.6	35.6	54.3	38.6

From the data of this table it appears that the amounts of both chlorine and HCO_3 recovered from the soils, after having been in contact with the manure 65 days, is very nearly directly proportional to the amounts of manure added; while in the case of the silica there is only a slight tendency to increase the amounts which can be recovered from the soil with water alone.

Comparing the two groups of soil, as has been done with other ingredients, the mean amounts recovered are as next stated.

Mean amounts recovered

	Of HCO_3.		Of Cl.		Of SiO_2.	
	4 poorer soils.	4 stronger soils.	4 poorer soils.	4 stronger soils.	4 poorer soils.	4 stronger soils.
	In parts per million of dry soil.					
Nothing added	13.0	38.0	2.5	2.0	9.45	31.35
25 tons manure	23.5	55.0	28.0	29.0	9.63	31.75
50 tons manure	33.5	71.5	52.0	54.5	7.50	32.60
100 tons manure	58.5	98.5	101.5	105.0	13.78	35.00
200 tons manure	102.3	160.0	195.8	212.5	17.43	40.78
	Change associated with the manure.					
25 tons manure	10.5	17.0	25.5	27.0	.18	.40
50 tons manure	20.5	33.5	49.5	52.5	−1.95	1.25
100 tons manure	45.5	60.5	99.0	103.0	4.33	3.65
200 tons manure	89.3	122.0	193.3	210.5	7.98	9.43

From the lower section of the table it is evident that only a slight, if any, change in the relation of the HCO_3 and Cl has been produced by using different amounts of manure.

AMOUNTS OF SALTS RECOVERED FROM MANURED SOILS BY CONTINUOUS PERCOLATION.

Near the close of January, 1904, 206 days after applying the manure to the soil, samples of the Janesville Loam and of the Norfolk Sand, to which manure had been applied at the rate of 200 tons per acre, were packed in the fresh, moist condition about Pasteur filters, inside the perforated cylinders described in Bulletin "B," p. 81.* In this condition distilled water was caused to flow slowly but continuously through layers of these soils 3-16 of an inch thick, until 6000 c. c. had been collected. As these soils had never been dried, the rate of percolation soon became very slow in the Janesville Loam and it required nearly 36 hours to get the 6 liters of water through this soil. The pressure on the Norfolk Sand was maintained low enough so that the same amount of time was required in collecting the 6000 c. c. of solution from it.

*Bureau of Soils. "B," Amounts of Plant Food Readily Recoverable from Field Soils with Distilled Water.

In these percolation experiments the amounts of dry soil used were, for the Janesville Loam 119.2 grams and for the Norfolk Sand 154.3 grams.

In the next table there are given the amounts of the different ingredients recovered from these two soils by the percolation method after the manure had been 206 days in contact with them.

Water-soluble salts recovered from heavily manured soils by percolation.

	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million of dry soil.								
Janesville Loam..	104.62	94.56	93.12	193.86	63.26	222.33	372.22	50.30	17.69
Norfolk Sand	62.24	64.19	66.60	146.89	36.88	118.26	412.34	38.90	15.38
Difference	42.38	30.37	26.52	46.97	26.38	104.07	—40.12	11.40	2.31

There is thus, at this time, not only a large amount of each ingredient recovered from the soils, except chlorine and silica, but the differences between the amounts recovered from the two soils are also large and in the usual direction, less coming away from the poorer soil.

This latter relation is not what the writer had anticipated from the results which have already been given for these same soils, obtained at an earlier date, 65 days after applying the manure. It will be recalled that at that time the dried samples were treated in the usual manner, using 500 c. c. of water to 100 grams of soil, with vigorous stirring during 3 minutes. Bringing the amounts recovered by the two treatments into comparison, they stand as given in the next table.

Relative amounts of water-soluble salts recovered from heavily manured soils on different dates.

	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_3.
	In parts per million of dry soil.								
	Janesville Loam.								
After 65 days contact	68.60	162.50	64.72	3.86	89.00	192.00	110.00	225.00	54.30
After 206 days cont'ct	104.62	94.56	93.12	193.86	63.26	222 33	372.22	50.30	17.69
Change	+36.02	−67.94	+28.40	+190.00	−25.74	+30.33	+262.22	−174.70	−36.61
	Norfolk Sand.								
After 65 days contact	116.20	78.75	60.16	4.84	149.00	120.00	146.00	200.00	14.10
After 206 days cont'ct	62.24	64.19	66.60	146.89	36.88	118.26	412.34	38.90	15.3
Change	−53.96	−14.56	+6.44	+142.05	−112.12	−1.74	+266.34	−161.10	+1.28

If the observations made 206 days after applying the manure were reversed and the values which are assigned to the Norfolk Sand were credited to the Janesville Loam the relations would have been more nearly what it was expected would be found when they were brought into comparison, which was not done until this writing in the June following. There is nothing in the records which indicates that a transposition could have occurred and while it is not impossible that the jars containing the two solutions might have been reversed, it is not likely that this did take place.

If the results are properly credited in the table, we have the Janesville Loam absorbing potash and phosphoric acid more rapidly during 65 days than the Norfolk Sand, as, indeed, from the physical standpoint, would be expected, but also, 141 days later, the reverse relation is brought out, the Janesville Loam, imparting to the same amount of distilled water and in the same time, 104.6 parts of potash and 63.3 parts of phosphoric acid, while the Norfolk Sand gave up but 62.2 parts of potash and 36.9 of phosphoric acid. But perhaps this relation, after all, is demanded on account of so much larger surface over which the water flowed in passing through the Janesville Loam. So much less was the frictional surface presented by the Norfolk Sand that the 6000 c.c. of water could have been passed through it, under the pressure maintained on the Janesville Loam, in 3 instead of 36 hours. Moreover, the depth of

the current, flowing over the surfaces of the grains in the coarse soil, must have been greater and this would tend to cause the concentration to be less.

If it is true that the soils which absorb the largest amounts of the essential plant foods, carrying them within and about their granular units, only retain them, after such absorption has taken place, in conditions which permit these ingredients to pass again into solution when conditions change, such a relation would appear to be in harmony with the observed relations of yield on such soils.

AMOUNTS OF WATER-SOLUBLE SALTS ADDED TO THE 8 SOIL TYPES WITH THE DIFFERENT QUANTITIES OF MANURE APPLIED.

A colorimetric determination was made of the water-soluble salts which could be recovered from the manure used in the experiments here under consideration and the results found, after washing a quantity of the manure during three minutes in distilled water, are given below:

Readily water-soluble salts recovered from fresh cow dung with distilled water.

K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
In parts per million of dry matter.								
3120	2010	2096.4	177.87	8208	525	747	2640	614.5

The gravimetric determinations for potash, lime, magnesia and phosphoric acid cited on p. 24 showed that there was present in the manure 2.327 times as much potash as was recovered in the brief treatment with distilled water; 5.244 times as much lime; 2.764 times as much magnesia; and 2.758 times as much phosphoric acid, as HPO_4.

In the next table there are given the amounts of readily water-soluble salts which were added to the different soil types with the manure, on the basis of the analysis of the manure, and taking into account the amount of moisture present in the soil when the manure was added.

Amounts of readily water-soluble salts added to the 8 soil types with the different amounts of manure applied.

	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million of dry soil.								
	Soils to which 25.22 tons of manure were added per acre.								
Norfolk Sandy Soil.....	26.78	17.25	17.99	1.53	74.44	2.79	6.41	22.66	5.27
Selma Silt Loam.......	27.83	17.93	18.70	1.59	73.21	2.90	6.66	23.55	5.48
Norfolk Sand..........	27.01	17.40	18.15	1.54	71.05	2.81	6.47	22.85	5.32
Sassafras Sandy Loam.	28.25	18.20	18.98	1.61	72.63	2.94	6.76	23.85	5.56
Hagerstown Clay Loam	29.56	19.04	19.86	1.68	77.74	3.08	7.07	25.01	5.82
Hagerstown Loam	29.81	19.20	20.03	1.70	78.42	3.11	7.14	25.22	5.87
Janesville Loam	30.27	19.50	20.33	1.73	79.64	3.15	7.25	25.61	5.96
Miami Loam	29.27	18.86	19.67	1.67	77.01	3.05	7.01	24.77	5.77
	Soils to which 50.43 tons of manure were added per acre.								
Norfolk Sand Soil.....	53.55	34.50	35.98	3.05	148.88	5.58	12.82	45.31	10.55
Selma Silt Loam.......	55.65	35.85	37.38	3.17	146.41	5.80	13.33	47.09	10.96
Norfolk Sand...........	54.01	34.80	36.29	3.03	142.09	5.63	12.93	45.70	10.64
Sassafras Sandy Loam.	56.50	36.40	37.97	3.22	145.26	5.89	13.53	47.60	11.13
Hagerstown Clay Loam	59.12	38.07	39.71	3.37	155.48	6.16	14.15	50.01	11.64
Hagerstown Loam	59.62	38.41	40.06	3.40	156.84	6.21	14.27	50.45	11.74
Janesville Loam	60.54	39.00	40.66	3.45	159.27	6.30	14.49	51.23	11.92
Miami Loam	58.55	37.72	39.34	3.34	154.02	6.10	14.02	49.54	11.53
	Soils to which 100.87 tons of manure were added per acre.								
Norfolk Sandy Soil.....	107.10	69.00	71.97	6.11	297.76	11.16	25.64	90.63	21.10
Selma Silt Loam	111.31	71.71	74.79	6.35	292.83	11.59	26.65	94.19	21.92
Norfolk Sand.........	108.02	69.59	73.58	6.16	284.18	11.25	25.96	91.40	21.28
Sassafras Sandy Loam.	113.01	72.80	75.93	6.44	290.52	11.77	27.06	95.20	22.26
Hagerstown Clay Loam	118.23	76.14	79.42	6.74	310.87	12.31	28.30	100.02	23.24
Hagerstown Loam	119.24	76.81	80.12	6.80	313.69	12.42	28.55	100.98	23.48
Janesville Loam	121.08	78.01	81.31	6.90	318.54	12.61	28.90	102.45	23.85
Miami Loam	117.15	75.44	78.68	6.68	308.04	12.20	28.03	99.08	23.06
	Soils to which 201.73 tons of manure were added per acre.								
Norfolk Sandy Soil.....	214.21	138.01	143.94	12.21	595.52	22.31	51.29	181.26	42.20
Selma Silt Loam	202.62	142.41	149.56	12.69	585.65	23.19	53.30	188.37	43.85
Norfolk Sand..........	216.05	139.18	147.18	12.32	568.36	22.50	51.73	182.81	42.55
Sassafras Sandy Loam.	226.02	145.61	151.86	12.88	581.05	23.54	54.12	190.40	44.51
Hagerstown Clay Loam	238.46	152.30	158.85	13.48	621.94	24.62	56.59	200.05	46.56
Hagerstown Loam	238.47	153.62	160.24	13.60	627.38	24.84	57.10	201.78	46.97
Janesville Loam	242.16	156.02	162.62	13.81	637.08	25.22	57.98	204.90	47.70
Miami Loam	234.30	150.87	157.35	13.35	616.09	24.39	56.07	198.15	46.12

From this table it will be seen that there was added to the different soils, in readily water-soluble form, from 26.78 to 242.16 parts per million of potash and a total, according to the gravimetric analysis, of 62.31 parts per million with the 25 tons and 563.6 parts with the 200 tons of manure per acre. Of phosphoric acid amounts were added, in water-soluble form, ranging from 71.05 to 637.08 parts per million of the dry soil; and, as a total, amounts ranging from 193.5 to 1,758 parts per million. The amounts of salts which have been added to these

soils, even with 200 tons of manure per acre, are less in proportion to the soil, than were used in the studies of absorption phenomena by the investigators cited in Bulletin D, pages 114 to 168.

AMOUNTS OF SALTS ADDED TO THE SOILS WITH THE MANURE, WHICH WERE NOT RECOVERED BY WASHING IN DISTILLED WATER.

If the amounts of water-soluble salts recovered from the soils to which no manure had been added and those which were added with the manure are considered as the amounts which were present in the several samples at the time they were examined, 65 days after they were manured, the differences between these sums and the amounts which were recovered will represent the quantities which were held back by the soils. In the next table a comparison is made of the averages from the four poorer and from the four stronger soils for each of the different amounts of manure which had been added to them.

Mean amounts of salts not recovered from soil 65 days after being treated with stable manure.

	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million of dry soil.								
	Soils to which 25.22 tons of manure were added per acre.								
Four stronger soils retained	25.46	9.14	21.29	93.39	77.85	−16.15	−9.83	−1.85	5.94
Four poorer soils retained	19.76	3.98	17.83	82.28	69.39	−32.14	−3.92	−2.27	5.23
	Soils to which 50.43 tons of manure were added per acre.								
Four stronger soils retained	47.79	13.85	41.26	94.93	150.40	−28.31	−19.27	−2.19	10.89
Four poorer soils retained	38.38	23.27	36.28	83.84	129.76	−43.27	--7.35	−3.07	12.77
	Soils to which 100.87 tons of manure were added per acre.								
Four stronger soils retained	98.68	32.15	61.44	135.40	295.68	−56.11	−32.05	−2.36	20.16
Four poorer soils retained	62.01	44.79	50.01	83.83	256.02	−70.06	−19.17	−6.14	17.31
	Soils to which 201.73 tons of manure were added per acre.								
Four stronger soils retained	169.25	85.50	121.53	172.43	551.87	−81.23	−65.08	−9.28	37.84
Four poorer soils retained	100.53	95.30	99.06	96.26	475.87	−89.61	−36.64	−7.54	35.30

From the data of this table it appears that all but three of the ingredients of the manure which were readily soluble in distilled water, have been held back by the soils in amounts which have increased a little less than in proportion to the amounts added. The SO_4, HCO_3 and Cl have, without exception, gone into solution in increasing quantities as the amounts of manure were increased. In other words, all of these ingredients that were shown to be present in the unmanured soil plus all that were added to the soils were recovered after 65 days of contact, and in addition thereto the amounts which are given in the table, designated by minus signs.

The mean amounts of the different salts actually recovered from the two groups of soils after 65 days of contact with the manure are given in the next table.

Mean amounts of salts recovered from the four poorer and four stronger soils after 65 days' contact with different amounts of manure.

	K.	Ca.	Mg.	NO_3.	HPO_4	SO_4.	HCO_3	Cl.	SiO_2.
	In parts per million of dry soil.								
	Soils to which 25.22 tons of manure were added per acre.								
Recovered from 4 stronger soils	21.07	88.69	22.74	70.91	8.70	99.25	55.00	29.00	31.70
Recovered from 4 poorer soils	19.52	54.50	8.97	12.74	6.55	70.00	23.50	28.00	9.63
	Soils to which 50.43 tons of manure were added per acre.								
Recovered from 4 stronger soils	28.47	103.13	27.13	35.38	14.35	114.50	71.50	54.50	32.60
Recovered from 4 poorer soils	28.35	53.00	12.06	2.86	19.00	84.00	33.50	52.00	7.50
	Soils to which 100.87 tons of manure were added per acre.								
Recovered from 4 stronger soils	37.05	123.13	42.55	52.88	27.95	148.50	98.50	105.00	35.03
Recovered from 4 poorer soils	57.15	66.87	32.40	10.43	38.40	116.50	58.50	101.50	13.78
	Soils to which 201.73 tons of manure were added per acre.								
Recovered from 4 stronger soils	85.90	149.38	62.85	3.63	82.10	186.00	160.00	212.50	40.78
Recovered from 4 poorer soils	121.25	86.88	57.17	4.25	110.38	147.25	102.25	195.75	17.43

From this table it will be seen that with 25 tons of manure per acre the four stronger soils, after 65 days, gave over to the

solution more of every ingredient than the four poorer soils did. With 50 tons per acre the amounts of potash are the same in both groups and the stronger soils have yielded less phosphoric acid, but, for the other ingredients, more than the poorer soils. Where 100 tons of manure have been applied the stronger soils have yielded less of both potash and phosphoric acid but more of all other ingredients; and practically the same can be said of the soils where 200 tons of manure per acre have been applied.

If the amounts of the different ingredients which were recovered from the soils to which no manure was added are subtracted from the amounts which were recovered from the soils to which the different amounts of manure were added, the differences will show the effect of the stable manure upon the salts which may be recovered from these soils with water alone, 65 days after the manure has been applied. The next table gives these results.

Amounts of salts which manured soils yield to distilled water more than the same soils do unmanured.

	K.	Ca.	Mg.	NO_3.	HPO_4	SO_4.	HCO_3	Cl.	SiO_2.
	In parts per million of dry soil.								
	Soils to which 25.22 tons of manure were added per acre.								
Excess:									
From 4 stronger soils	4.27	8.31	−1.37	−91.74	1.60	19.25	17.00	27.00	.40
From 4 poorer soils...	7.70	13.62	.63	−75.01	3.45	35.00	10.50	25.50	.17
	Soils to which 50.43 tons of manure were added per acre.								
From 4 stronger soils	11.67	22.75	3.01	−127.27	6.00	34.50	33.50	52.50	1.05
From 4 poorer soils...	16.55	12.12	3.72	−84.89	15.90	49.00	20.50	49.50	−1.65
	Soils to which 100.87 tons of manure were added per acre.								
From 4 stronger soils.	20.25	42.75	18.43	−109.77	19.60	68.50	60 .50	103.00	3.67
From 4 poorer soils...	45.85	26.00	24.06	−77.32	35.30	31.50	45.00	99.00	4.32
	Soils to which 201.73 tons of manure were added per acre.								
From 4 stronger soils.	69.10	68.99	38.73	−159.02	73.75	106.00	122.00	210.50	9.42
From 4 poorer soils..	109.70	46.00	48.83	−83.50	107.27	112.50	89.25	193.25	7.97

From this table it appears that 25 tons of fresh cow manure applied to the four stronger soils yields in readily water-soluble form after 65 days, 4.27 parts per million of the dry soil more

of potash, and 1.6 more of phosphoric acid that the unmanured soils did; while the same dressing applied to the poorer soils produced a gain of 7.7 parts of potash and 3.4 parts of phosphoric acid. When 50 tons of manure were applied the gains were 11.67 and 6 parts for the stronger soils and 16.55 and 15.90 parts per million of potash and phosphoric acid for the poorer soils, respectively. When 100 tons of manure are applied the differences then become 20.25 and 19.60 for the stronger soils and 45.85 and 35.30 for the poorer, for the potash and phosphoric acid, respectively, in parts per million of the dry soil; while at 200 tons the gains become enormous, reaching 69.10 and 73.75 for the stronger soils and 109.70 and 107.27 for the poorer, of potash and phosphoric acid, respectively, in parts per million of the dry soil.

There is, therefore, abundant proof in these observations that large dressings of manure do increase in a high degree the water-soluble salts which may be recovered from a soil.

INFLUENCE OF LIME AND STABLE MANURE ON WATER-SOLUBLE SALTS IN SOILS.

In these experiments composite samples of the surface foot of soil of each type were procured, and after mixing and bringing them to good moisture condition each sample was divided into four lots of 15 pounds each, to one of which nothing was added, to another lime at the rate of 1 ton per acre, to another 10 tons of air-dry stable manure per acre, and to the fourth 10 tons of air-dry manure and 1 ton of lime per acre. The soils were kept at nearly constant moisture and good aeration conditions during a period of about fifty days, at the end of which time the soluble salts were determined, with the results given in the following table:

Changes in amounts of nitrates, expressed as NO_3, after fifty days.

Periods of Experiment.	Sandhill.	Selma Silt Loam.	Norfolk Sand.	Goldsboro Compact Sandy Loam.	Norfolk Fine Sandy Loam.	Pocoson.
	In parts per million of dry soil.					
	Where nothing was added to soil.					
Found at close............	17.10	136.5	117.0	71.5	92.0	198.0
Present at start..........	3.76	42.2	19.9	19.3	15.7	41.6
Amount produced....	13.34	94.3	97.1	52.2	76.3	156.4
	Where lime alone was added at the rate of 1 ton per acre.					
Found at close............	99.20	150.0	132.0	84.0	105.6	205.0
Present at start..........	3.76	42.2	19.9	19.3	15.7	41.6
Amount produced....	95.44	107.8	112.1	64.7	89.9	163.4
	Where manure alone was added at the rate of 10 tons, air-dry, per acre.					
Found at close............	80.00	193.0	166.0	104.0	114.4	213.0
Present at start..........	3.76	42.2	19.9	19.3	15.7	41.6
Amount produced ...	76.24	150.8	146.1	84.7	99.7	171.4
	Where both lime and manure were added at rates of 1 and 10 tons per acre, respectively.					
Found at close............	124.00	220.0	181.0	116.0	132.0	231.5
Present at start..........	3.76	42.2	19.9	19.3	15.7	41.6
Amount produced ...	120.24	177.8	161.1	96.7	116.3	189.9

From this table it will be seen that in the extremely sandy type of soil the addition of lime alone allowed the rate of nitrification to exceed that which occurred in two of the other types to which only lime was added, and also that the lime materially increased the rate of nitrification in them all. The increase during the fifty days over that present in the soil at the start, for the six types, was enough to amount to 286, 323, 336, 194, 269, and 490 pounds per acre in the surface foot, taking the mean weight of the soil at 3,000,000 pounds, and stating the amounts in the order in which the soils are named in the table. It is noteworthy, too, that the lime alone had a greater influence in stimulating nitrification in the Sandhill type than did the 10 tons of stable manure alone, while in the case of the Pocoson neither the lime nor the manure alone, nor the two combined, stimulated the rate of nitrification in as marked a way when compared with the rate which was maintained in the same untreated soil, which, however, was far higher than that

in any other case. In other words, the untreated Pocoson soil was nearly in prime condition for nitrification, so that the combined effect of the manure and lime increased the nitrates (NO_3) produced at the rate of only 101 pounds per acre in the fifty days.

The changes which occurred in the amounts of sulphates (SO_4) recoverable by washing three minutes in distilled water were also marked, and are given in the following table:

Amounts of sulphates, expressed as SO_4, *recoverable after about fifty days.*

Periods of Experiment	Sandhill.	Selma Silt Loam.	Norfolk Sand.	Goldsboro Compact Sandy Loam.	Norfolk Fine Sandy Loam.	Pocoson.
	In parts per million of dry soil.					
	Where nothing was added to soil.					
Found at close	3.1	60.1	29.5	59.8	53.0	28.1
Present at start	3.1	43.7	20.8	33.0	16.1	13.2
Change	0.0	16.4	8.7	26.8	36.9	14.9
	Where lime was added at the rate of 1 ton per acre.					
Found at close	9.2	83.2	48.4	80.9	65.3	36.2
Present at start	3.1	43.7	20.8	33.0	16.1	13.2
Change	6.1	39.5	27.6	54.1	49.2	23.0
	Where manure was added at the rate of 10 tons, air-dry, per acre.					
Found at close	5.1	78.6	54.8	70.4	80.0	38.2
Present at start	3.1	43.7	20.8	33.0	16.1	13.2
Change	2.0	34.9	34.0	37.4	63.9	25.0
	Where both lime and manure were added, at the rates of 1 and 10 tons per acre, respectively.					
Found at close	11.4	101.7	59.0	93.6	95.2	47.2
Present at start	3.1	43.7	20.8	33.0	16.1	13.2
Change	8.3	58.0	38.2	60.6	79.1	34.0

From this table it is clear that, associated with the nitrification, there has been a liberation of sulphates, apparently more from the materials of the original soils than from the materials added, and in larger amounts where the lime and manure are added together.

The changes in the amounts of phosphates have all been in the opposite direction from those of either the nitrates or the sulphates, as is shown in the following table:

Changes in amounts of water-soluble phosphates, expressed as HPO_4, after fifty days.

Periods of Experiment.	Sandhill.	Selma Silt Loam.	Norfolk Sand.	Goldsboro Compact Sandy Loam.	Norfolk Fine Sandy Loam.	Pocoson.
	In parts per million of dry soil.					
	Where nothing was added to soil.					
Present at start	6.90	14.20	11.50	7.20	8.12	18.00
Found at close	1.46	2.46	1.49	3.78	2.30	2.39
Change	5.44	11.74	10.01	3.42	5.82	15.61
	Where lime was added at the rate of one ton per acre.					
Present at start	6.90	14.20	11.10	7.20	8.12	18.00
Found at close	1.46	3.28	2.99	3.78	2.30	3.19
Change	5.44	10.92	8.51	3.42	5.82	14.81
	Where manure was added at the rate of 10 tons, air-dry, per acre.					
Present at start	6.90	14.20	11.50	7.20	8.12	18.00
Found at close	2.18	4.92	3.74	4.54	4.22	3.99
Change	4.72	9.28	7.76	2.66	3.90	14.01
	Where both manure and lime were added at the rates of 1 and 10 tons per acre, respectively.					
Present at start	6.90	14.20	11.50	7.20	8.12	18.00
Found at close	3.28	6.18	4.48	4.54	3.83	4.79
Change	3.62	8.02	7.02	2.66	4.29	13.21

Associated with the increased amounts of nitrates and sulphates and of other water-soluble salts, and with the changed physical and other conditions which favor the increased rates of nitrification, there were other changes occurring which placed the phosphates in conditions preventing their recovery from the soils by single three-minute washings in distilled water in as large amounts as were recovered from the same soils immediately prior to their being placed in the nitrification experiment. The soils were under quite different physical conditions, so far as soil moisture and soil air were concerned, but how far these may have determined the changes referred to cannot yet be stated; but what seem to be comparatively slight physical differences are undoubtedly responsible directly or indirectly for very different results in the amounts of some of the water-soluble salts recoverable from different soils. The truth of this statement will be clear from a comparison of the amounts of

nitrates recovered from the different layers of the six soils under consideration after they had stood under the mulched and unmulched conditions where all other conditions were the same so far as we know, except in so far as the condition of the two surfaces affected the soil moisture and soil air relations, and through those the differences in water-soluble salts recoverable by our method of washing. The table following shows the differences developed at different depths below the depth of the 3-inch mulch and below 3 inches in the soil not mulched:

Differences in the amounts of nitrates, expressed as NO_3, *in six soil types at different depths below surface under 3-inch mulches and where surface was firm.*

Depth.	Sandhill.		Selma Silt Loam.		Norfolk Sand.		Goldsboro Compact Sandy Loam.		Norfolk Fine Sandy Loam.		Pocoson.	
	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.
Inches.	In parts per million of dry soil.											
3 to 6....	4.0	4.6	98.0	26.8	52.8	9.1	46.8	8.2	25.0	12.3	91.2	33.2
6 to 9....	6.2	4.5	52.4	28.1	46.8	11.5	35.8	7.0	25.3	11.0	78.1	26.4
9 to 12....	3.8	4.7	52.9	24.6	13.9	9.3	30.6	5.7	16.1	9.1	52.0	27.2
12 to 15....	3.9	2.6	32.5	20.5	16.9	7.3	27.2	4.8	16.2	7.9	26.5	19.6
15 to 18....	1.9	2.3	20.4	15.2	3.1	7.8	7.0	2.8	7.8	5.7	13.7	10.7

It will be seen that we have, in every one of the six soil types, profound differences in their nitrate content at the several depths below the surface, which not only emphasizes the point under consideration but also the influence of tillage on the water-soluble content of the soil already referred to. The larger amounts of nitrates shown here under the mulched surfaces are not due simply to the fact that less has been carried above the 3-inch layer, where the soils were mulched, for the total amounts recoverable from the full 18 inches were larger. The figures in the table show in an emphatic manner how influential the 3-inch mulch has been in holding the nitrates in the zone of greatest root development, where they are needed and can best be obtained by the plants.

The amounts of silica, chlorine and of bicarbonates were also determined in these soils at the same time and the mean values for the six soil types are given in the next table, together with those for the other ingredients:

Mean amounts of water-soluble salts recovered from 6 soil types under different treatments.

	NO_3.	HPO_4	SO_4.	HCO_3	Cl.	SiO_3.	Total.
	In parts per million of dry soil.						
Where nothing is applied	105.35	2.31	38.92	12.77	19.62	3.90	182.87
Where 1 ton of lime is applied	129.30	2.83	53.88	18.55	18.85	3.80	227.21
Where 10 tons of manure are applied	145.07	3.93	54.52	16.16	28.38	3.37	251.43
Where 1 ton lime and 10 tons manure are applied	167.48	4.51	68.01	16.71	25.67	3.49	285.87

From this table it is seen that lime has increased each ingredient determined, except chlorine and silica. The manure alone has increased all ingredients except silica; the nitric acid 40 parts per million, phosphoric acid 1.63 parts, the sulphates 15.6 parts, and the chlorine 8.76 parts; while the lime and the manure combined have produced much the largest gain of each of the first three ingredients of the table.

Influence of Manure Upon the Water-Soluble Salts Recovered from Plants.

At the same time samples of soil were taken, others from the corn and potatoes growing upon the soils, were collected and examined for the water-soluble salts which could be recovered from them, the object being to ascertain whether the differences observed in the soil were also reflected in the sap of the crops themselves. In procuring the solutions for examination, the plant samples were first cut fine and dried water-free at 100° C, when a weighed quantity of the crisp material was rubbed down in a mortar and after this a small quantity of distilled water added so as to form a thick paste. In this condition the material was crushed in the mortar by rubbing during from 3 to 5 minutes; after which enough more distilled water was added to equal 100 times the dry weight of the sample crushed. In this condition, carbon black was added and the solution allowed to stand 20 to 30 minutes to be decolorized.

In the following table there are given the amounts of water-soluble salts which were recovered from corn and potatoes growing upon the sub-plots to which 15 tons of manure were added and upon those to which nothing had been applied:

Amounts of water-soluble salts recovered from corn and potatoes growing upon manured and unmanured ground.

	Goldsboro, North Carolina		Upper Marlboro, Maryland.		Lancaster, Pennsylvania.		Janesville, Wisconsin.	
	Norf'lk Sandy Soil.	Selma Silt Loam.	Norfolk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hag-erst'wn Loam.	Janes-ville Loam.	Miami Loam.
	In parts per million of dry plant.							
	Water-soluble potash in corn plants 60 days after planting.							
15 tons manure ...	19435	16980	41050	40350	25430	33880	46450	29050
Nothing added ...	13920	16560	22720	30480	19520	20000	13920	23940
Difference	5515	420	18330	9870	5910	13880	32530	5710
	Water-soluble potash in potato plants 65 days after planting.							
15 tons manure ...	22720	20000	27440	33120	24400	48800	32000	30960
Nothing added ...	18440	16280	24440	14800	18760	42400	25160	21200
Difference	4280	3720	3000	18320	5640	6400	6840	9760
	Water-soluble lime in corn plants 60 days after planting.							
15 tons manure ...	1200	1200	1060	1370	1925	1500	1750	1500
Nothing added ...	1800	2800	5200	5000	5800	5000	5000	5500
Difference	−600	−1600	−4140	−3630	−3875	−3500	−3250	−4000
	Water-soluble lime in potato plants 65 days after planting.							
15 tons manure ...	5900	4600	260	3600	4800	2900	6200	5900
Nothing added ...	3200	4500	480	3950	5600	3200	6400	5500
Difference	2700	100	−220	−350	−800	−300	−200	400
	Water-soluble magnesia in corn plants 60 days after planting.							
15 tons manure ...	787.0	788.0	714.6	1160.8	3558.0	2385.6	1876.8	2192.0
Nothing added ...	845.6	964.8	1801.6	2489.6	7027.2	4148.8	4563.2	6848.0
Difference	−58.6	−176.8	−1087.0	−1328.8	−3469.2	−1763.2	−2686.4	−4656.0
	Water-soluble magnesia in potato plants 65 days after planting.							
15 tons manure ...	2977.6	2321.6	744.4	1244.8	4643.2	2854.4	4643.2	3912.0
Nothing added ...	1488.8	2208.8	1521.6	4278.4	7204.8	2913.6	5073.6	4979.2
Difference	1488.8	112.8	−777.2	−3033.6	−2561.6	−59.2	−430.4	−1067.2
	Water-soluble NO_3 in corn plants 60 days after planting.							
15 tons manure ...	358.8	1321.6	632.4	7648.0	17104.0	17104.0	29056.0	17344.0
Nothing added ...	403.2	830.4	2640.0	2344.0	12640.0	22336.0	20768.0	20032.0
Difference	−44.4	491.2	−2007.6	5304.0	4464.0	−5232.0	8288.0	−2688.0
	Water-soluble NO_3 in potato plants 65 days after planting.							
15 tons manure ...	7264.0	18176.0	2153.6	1491.2	24200.0	25960.0	33040.0	25960.0
Nothing added ...	6320.0	12112.0	29056.0	8304.0	17720.0	27920.0	29040.0	20160.0
Difference	944.0	6064.0	−26902.4	−6812.8	6480.0	−1960.0	4000.0	5800.0

Amounts of water soluble salts recovered from corn and potatoes growing upon manured and unmanured ground—Continued.

	Goldsboro, North Carolina.		Upper Marlboro, Maryland.		Lancaster, Pennsylvania.		Janesville, Wisconsin.	
	Norf'lk Sandy Soil.	Selma Silt Loam.	Norfolk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hag-erst'wn Loam.	Janesville Loam.	Miami Loam.
	In parts per million of dry plant.							
	Water-soluble phosphates, as HPO_4, in corn plants 60 days after planting.							
15 tons manure ...	5526.0	4238.0	9228.0	6960.0	4900.0	5510.0	6552.0	5480.0
Nothing added ...	4720.0	4656.0	6120.0	6016.0	7040.0	6000.0	6704.0	4208.0
Difference	806.0	−418.0	3108.0	944.0	−2140.0	−490.0	−152.0	1272.0
	Water-soluble phosphates, as HPO_4, in potato plants 65 days after planting.							
15 tons manure ...	4724.0	4864.0	4468.0	4948.0	4208.0	3896.0	4244.0	4572.0
Nothing added ...	4864.0	4844.0	4252.0	4848.0	4228.0	3424.0	3960.0	3932.0
Difference	−140.0	20.0	216.0	100.0	−20.0	472.0	284.0	640.0
	Water-soluble sulphates, as SO_4, in corn plants 60 days after planting.							
15 tons manure....	520.0	1480.0	0.0	200.0	2550.0	2450.0	2090.0	1400.0
Nothing added....	1220.0	920.0	380.0	290.0	5200.0	2950.0	3100.0	1420.0
Difference.....	−700.0	560.0	−380.0	−90.0	−2650.0	−500.0	−1010.0	−20.0
	Water-soluble sulphates, as SO_4, in potato plants 65 days after planting,							
15 tons manure....	4400.0	3200.0	2080.0	1700.0	2560.0	2800.0	2880.0	3120.0
Nothing added....	1280.0	3040.0	3680.0	1440.0	3360.0	4320.0	2800.0	2960.0
Difference.....	3120.0	160.0	−1600.0	260.0	−800.0	−1520.0	80.0	160.0
	Water-soluble bicarbonates, as HCO_3, in corn plants 60 days after planting.							
15 tons manure....	7950.0	4100.0	31700.0	15500.0	6200.0	18200.0	10700.0	5700.0
Nothing added....	4000.0	4800.0	26400.0	24600.0	9400.0	12600.0	16400.0	14200.0
Difference.....	3950.0	−700.0	•5300.0	−9100.0	−3200.0	5600.0	−5700.0	−8500.0
	Water-soluble bicarbonates, as HCO_3, in potato plants 65 days after planting.							
15 tons manure....	6000.0	6000.0	15000.0	11400.0	8400.0	10800.0	9800.0	11000.0
Nothing added....	5600.0	6400.0	7800.0	11400.0	9400.0	10200.0	9400.0	11800.0
Difference.....	400.0	−400.0	7200.0	0.0	−1000.0	600.0	400.0	−800.0

Amounts of water-soluble salts recovered from corn and potatoes growing upon manured and unmanured ground—Continued.

	Goldsboro, North Carolina		Upper Marlboro, Maryland.		Lancaster, Pennsylvania.		Janesville, Wisconsin.	
	Norf'lk Sandy Soil.	Selma Silt Loam.	Norfolk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hag-erst'wn Loam.	Janesville Loam.	Miami Loam.
	Water soluble chlorides, as Cl. in corn plants 60 days after planting.							
15 tons manure....	3700.0	4400.0	3800.0	8950.0	7900.0	11600.0	11050.0	10850.0
Nothing added....	2300.0	3700.0	2000.0	6000.0	8500.0	4300.0	7100.0	2900.0
Difference.....	1400.0	700.0	1800.0	2950.0	4400.0	7300.0	3950.0	7950.0
	Water-soluble chlorides, as Cl. in potato plants 65 days after planting.							
15 tons manure ...	15500.0	5700.0	3700.0	17000.0	5200.0	3600.0	6900.0	7400.0
Nothing added....	4000.0	4600.0	2400.0	3200.0	3700.0	1400.0	1200.0	1600.0
Difference.....	11500.0	1100.0	1300.0	13800.0	1500.0	2200.0	5700.0	5800.0
	In parts per million of dry plant.							
	Water-soluble silica, or silicates, as SiO_2, in corn plants 60 days after planting.							
15 tons manure....	51.2	83.7	288.2	211.1	138.1	234.3	173.6	135.8
Nothing added....	114.8	139.8	80.8	93.2	124.0	119.2	105.6	90.0
Difference.....	−63.6	−56.1	207.4	117.9	14.1	115.1	68.0	45.8
	Water-soluble silica, or silicates, as SiO_2, in potato plants 65 days after planting.							
15 tons manure....	180.0	118.0	142.8	155.2	90.0	114.8	118.0	164.0
Nothing added....	118.0	118.0	111.6	155.2	186.0	86.8	130.4	152.0
Difference.....	62.0	0.0	31.2	0.0	−96.0	28.0	−12.4	12.0

From this table it will be seen that, at 60 and 65 days from planting, both corn and potatoes carry in their sap notable amounts of potash. Moreover, on each and every soil type and for both crops more potash has been recovered from the soils to which the manure had been applied. From the manured ground, too, have come the largest yields and the potash recovered from the soil has been shown to rise and fall with the yields.

INFLUENCE OF MANURE UPON THE AMOUNTS OF POTASH RECOVERED FROM SOILS BY PLANTS.

If we combine the data in the table, making two groups, under the stronger and poorer soils, they will stand as next given:

Mean amounts of potash recovered from corn and potatoes growing upon manured and unmanured ground.

	Four Stronger Soils.		Four Poorer Soils.	
	Nothing added.	15 tons manure.	Nothing added.	15 tons manure.
	In parts per million of dry plant.			
Corn	19345	33703	20920	29454
Potatoes	26880	25820	18490	25820
Average	23113	29762	19705	27637
Nothing added	23113	23113	19705	19705
Difference	00000	6649	00000	7932
Percentage relations	100.0	128.8	100.0	140.3

It is thus shown that the crops on the manured ground have recovered 29 per cent. more potash from the four stronger soils and forty per cent. more from the four poorer soils, where the 15 tons of manure had been applied. Associated with these differences in the amounts of potash recovered by the plants there have been the following differences in yield of water-free dry matter in shelled corn and potatoes, using 21.1 per cent. as the estimated amount of dry matter in the tubers as a basis for calculating the dry matter produced in this crop:

Mean amounts of dry matter produced by corn and potatoes on manured and unmanured ground.

	Four Stronger Soils.		Four Poorer Soils.	
	Nothing added.	15 tons manure.	Nothing added.	15 tons manure.
	Lbs.	Lbs	Lbs.	Lbs.
Corn, per acre	2878.96	3460.52	1225.00	2241.57
Potatoes, per acre	2133.84	3209.31	683.26	1227.51
Average, per acre	2506.40	3334.92	954.13	734.54
Nothing added	2506.40	2506.40	954.13	954.13
Difference	0000.00	828.52	000.00	780.41
Percentage relation	100.0	133.1	100.0	181.8

These relations of yield appear to be not only in accord with the amounts of potash found, but also in accord with what is demonstrated regarding the functions of potash in plant physiology. Loew* points out that "the paramount importance of potassium salts for every living cell is firmly established" and holds that, in green plants, they are concerned not only in the upbuilding of carbohydrates but in that of protein bodies as well.

Various observers have shown that when plants are placed under conditions where all potash salts are excluded, not only does the formation of starch stop altogether but that whatever may have been present disappears and ultimately growth stops; but that, on the admission of potash salts into the plants again, the formation of starch is renewed and growth carried forward. With vital functions like these so intimately related to this element, it is easy to understand why deficiencies of potash in forms available to crops stand next, perhaps, to deficiencies in nitrates in determining small yields. Indeed, it has transpired in the constant cropping series begun by the writer at the Wisconsin Agricultural Experiment Station in 1896, where 700-pound lots of a strong virgin soil were placed under corn, oats, potatoes and clover, and forced to produce two to three crops annually, that this year (1903) when Prof. Whitson divided the series into groups to test, through the application of potash, nitrates, and phosphates, which ingredient most increased the yield (then fallen far below the first crops), the results have shown in a very striking manner that the addition of potash had far greater effect than did the addition of either of the other salts, and appear to indicate that these soils had either become absolutely deficient in potash during the constant cropping, or else that the potash still remaining was not in such form as to come into solution and enter the crops with sufficient rapidity to meet their needs.

In the soil of the four plant evaporimeters† upon which 10 stalks of corn were matured on each of four soil types, there was a very appreciable decrease in the amounts of potash which

*United States Department of Agriculture, Bureau of Plant Industry, Bulletin No. 45, page 28.

†Bureau of Soils, Relation of Differences of Yield on 8 Soil-Types to Differences of Climatological Environment, p. 96, F. H. King.

could be recovered from the four soils by washing them in distilled water during three minutes, as shown by determination before and after the crops had occupied the ground; the results appear in the table which follows:

Amounts of water-soluble salts in the surface foot, under corn, at the beginning and close of the growing season.

	K.	Ca.	Mg.	NO_3.	HPO_4	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million of dry soil.								
	Norfolk Sandy Soil.								
In soil at start.... ...	5.61	25.50	10.70	20.46	2.85	45.50	−17	0	4.05
In soil at close	1.84	27.00	8.15	3.13	2.73	72.50	6	0	4.10
Change	-3.77	+1.50	−2.55	−17.33	−.12	+27.00	+23	0	+.05
	Norfolk Sand.								
In soil at start........	5.20	22.25	11.95	16.52	2.95	35.50	7	0	6.45
In soil at close........	2.38	41.30	9.51	6.25	3.80	77.50	14	0	4.70
Change......... ..	-2.82	+19.05	−2.44	−10.27	+.85	+42.00	+7	0	−1.75
	Hagerstown Clay Loam.								
In soil at start........	12.10	281.25	28.54	50.80	14.10	207.50	88	0	15.80
In soil at close........	6.68	243.80	32.36	26.92	12.90	256.30	124	0	15.10
Change..........	-5.42	−37.45	+3.82	−23.88	−1.20	+48.80	+36	0	−.70
	Janesville Loam.								
In soil at start...	6.92	215.65	24.11	68.55	19.70	150.00	46	0	23.55
In soil at close........	3.94	100.00	19.02	22.15	17.10	105.00	52	0	18.60
Change............	-2.98	-115.65	−5.09	−46.40	−2.60	−45.00	+6	0	−4.95
Average change.......	-3.75	−33.14	−1.57	−24.47	−.77	+18.20	+18	0	+1.84

There is thus shown, in each of the four cases, that a reduction has occurred in the amounts of potash which could be recovered from these soils at the close of the season, and this reduction was not confined to the surface foot, as will appear from the next table:

Changes in the amounts of potash which could be recovered from the surface three feet of four soils after cropping one season.

	Norfolk Sandy Soil.	Norfolk Sand.	Hagerstown Clay Loam.	Janesville Loam.
	In parts per million of dry soil.			
Change of potash (K) in 1st foot..	3.77	2.82	5.42	2.98
Change of potash (K) in 2d foot..	3.23	.68	5.92	3.05
Change of potash (K) in 3d foot..	+.07	1.26	6.00	3.01
Sum	6.93	4.76	17.34	9.04
Change in pounds per acre.......	26.84	17.23	54.55	27.87

It is thus seen that a change has occurred during the maturing of the crop of corn upon these four soils, which has made it possible to recover by the same treatment with distilled water from 17.23 to 54.55 pounds per acre less potash in the three feet of soil occupied by the roots of the corn; and it is clear that such a rate of decrease in the solubility of potash or in the amount of soluble potash present, could not be maintained through many seasons before the effect would be reflected in the yields of the crops, as, indeed, has been shown to have occurred in the Wisconsin series cited above:

INFLUENCE OF MANURE UPON THE AMOUNTS OF LIME AND MAGNESIA RECOVERED FROM SOILS BY PLANTS.

If the amounts of lime and magnesia found in the corn and potato plants are brought together from the general table and grouped under stronger and poorer soils, the results will stand as given in the next table:

Mean amounts of lime and magnesia recovered from corn and potatoes growing upon manured and unmanured ground.

	Amounts of Lime (Ca).				Amounts of Magnesia (Mg).			
	4 stronger soils.		4 poorer soils.		4 stronger soils.		4 poorer so ls.	
	Nothing added.	15 tons manure.	Nothing added.	15 tons manure.	Nothing added	15 tons manure.	Nothing added	15 tons manure.
	In parts per million of dry plant.							
Corn	4025	2711	2831	1623	4028	2610	1683	1155
Potatoes	4287	4275	2857	2256	5442	4804	2483	1693
Average	4156	3493	2844	1940	4735	3707	2083	1424
Nothing added	4156	4156	2844	2844	4735	4735	2083	2083
Difference	0000	−663	0000	−904	0000	−1028	0000	−659
centage relations	100.00	84.05	100.00	68.2	100.00	78.28	100.00	68.36

From this table it appears that, as an average, the plants growing upon the manured ground, the ones which were making, at the time of the examination, the most vigorous growth, and the ones which produced, in the end, the largest yields had, in their plant sap or in their tissues, in a form which could

be recovered by the treatment with water, relatively less of both lime and magnesia than did those growing upon the unmanured ground and which produced the smallest final yields.

If reference is made to the general table it will be seen that, for the corn, there are no exceptions to this statement among the individual data; that there is but one exception among the potatoes with magnesia; but that there are three exceptions with lime, one of which is percentagely large.

The observed relations of the three bases determined in the studies and here referred to, cannot be ascribed to a differential effect of the soils upon them, the manure holding these salts back, for it has been shown that more of all three bases existed in the manured soils in a form which could be recovered by washing in distilled water. The relations of lime and magnesia are, however, such as might be expected if the views of Loew* regarding the functions and movements of lime and magnesia in living tissues are correct. We refer specially to the statement, p. 56, that, "as a matter of fact, it is found that magnesia always increases where rapid development is taking place," and that "the calcium content increases with the mass of nuclear substance and chlorophyll bodies." If these statements are correct, and if the lime and magnesia thus accumulated become insoluble, or are otherwise held back from the solution, then there should be observed a greater reduction of the soluble lime and magnesia in the plant sap where the most vigorous growth is taking place. It is, of course, recognized that observations of this character are suggestive rather than demonstrative. Attention should also be called to the fact that the amounts in the table are relative to the dry matter and not absolute.

*United States Department of Agriculture, Bureau of Plant Industry, Bulletin No. 45.

INFLUENCE OF MANURE UPON THE AMOUNTS OF NITRIC AND PHOSPHORIC ACIDS RECOVERED FROM SOILS BY PLANTS.

Determining the mean values for the nitric acid and phosphoric acid recovered from the plants grown upon the manured and unmanured soils the values stand as given in the next table:

Mean amounts of nitric acid and of phosphoric acid recovered from corn and potatoes grown upon manured and unmanured ground.

	Amounts of Nitric Acid (NO_3).				Amounts of Phosphoric Acid (HPO_4).			
	4 stronger soils.		*4 poorer soils.*		*4 stronger soils.*		*4 poorer soils.*	
	Nothing added.	15 tons manure.	Nothing added	15 tons manure.	Nothing added.	15 tons manure.	Nothing added.	15 tons manure.
	In parts per million of dry plant.							
Corn	20152	18944	2490	1554	5611	5988	6488	5378
Potatoes	27290	23710	7271	13951	4230	3886	4501	4702
Average	23721	21327	4881	7753	4921	4937	5495	5040

This table shows no such sharp percentage differences as stand out clear and strong with the three bases. With the nitrates from both corn and potatoes, except on the poorer soils, the relation holds which occurred with the lime and magnesia, namely, a smaller relative amount in the plants which have made the most vigorous growth; and, with the nitric acid being transformed into organic nitrogen, this relation is what should be expected. With the phosphoric acid there is less indication of the manure having had any effect upon the percentage amounts recovered by the treatment of the plant samples with distilled water.

Comparing the absolute amounts of these two ingredients, which had been recovered from the soils by the plants at the time the samples were taken and which still remained in soluble form in their tissues, the relations will, of course, be quite different from those shown by the table. The relative amounts of dry matter existing in the crops under comparison at the time of observation are not known, but it is likely that the

ratios which did exist at the time were, approximately, the same as would be shown by the differences in the amounts of dry matter given in the table, p. 53. If calculations are made on the basis of those values it will be found that the absolute amounts of nitric and phosphoric acids which were recovered from the plants are largest from those which had grown upon the manured ground.

In the case of sulphates recovered from the plants, under the two conditions, there were larger relative amounts recovered from the corn growing upon the manured land, and also from the potatoes in the case of the stronger soils. This relation was, however, reversed in the potatoes from the poorer soils.

In view of the fact that the soil moisture has usually shown such large amounts of sulphates, when compared with those of other ingredients determined, it appears not a little remarkable that the plant sap should have been found to contain so little. The sulphur is, of course, appropriated as growth goes forward, and possibly the small amounts observed are due to absorption in this way.

In the case of chlorine, which has invariably been found in these soils in very small amounts, the relations are the reverse so far as the plants are concerned. Not only are relatively large amounts recovered from the plant tissues, but the differences between the amounts recovered from the plants grown upon the manured and unmanured ground are very large, and in the same direction as occurred in the case of potash. The relations are expressed in the next table:

Mean amounts of chlorine recovered from corn and potatoes grown upon manured and unmanured ground.

	FOUR STRONGER SOILS.		FOUR POORER SOILS.	
	Nothing added.	15 tons manure.	Nothing added.	15 tons manure.
	In parts per million of dry plant.			
Corn	4450	10350	3500	5213
Potatoes	1975	5775	3550	10475
Average	3213	8063	3525	7844
Nothing added	3213	3213	3525	3525
Difference	0000	4850	0000	4319
Percentage relations	100.00	250.95	100.00	222.52

It is here seen that the plants grown upon the manured ground have yielded to the treatment more than double the amounts of chlorine that were recovered from the plants which had grown upon the unmanured ground.

The observations here presented, both upon the soils and upon the plants which had grown upon the soils, make it clear that when farm yard manure is applied to fields it has the effect not only of increasing the yields but at the same time of increasing the amounts of water-soluble salts which can be recovered from the soils themselves and from the plants which have grown upon them.

Largest Returns from Stable Manure.

It will be clear from the data which have been presented, relative to the yields of corn and potatoes which have been secured through the application of 5, 10 and 15 tons of manure per acre, to different soil types, and also from the rates of nitrification which were observed when larger amounts of manure had been used, that a careful observation of results and good judgment are necessary in order to secure the largest returns from manure applied to land.

In general farming, there can be no question but that, it is much better to follow the practice of giving frequent and light dressings of manure to land rather than to apply large amounts at long intervals. A small increase of a few bushels of grain, potatoes or roots, or a few hundredweight increase of grass or hay per acre, steadily maintained over the whole farm year after year, will bring much larger returns than can be secured from high fertilization at long intervals, or continuously on small portions of the farm, while the balance receives little attention. One hundred tons of manure carefully applied to 10 or 15 acres well cared for will give larger returns, in general farming, than when the same amount is applied to four or five acres, as is often the case.

When too much manure is applied wasteful oxidations occur which destroy the organic matter at once, returning it direct to the atmosphere; and this may happen when an unsuccessful

effort has been made to apply a moderate amount of manure, by distributing it unevenly over the surface. When manure is applied directly beneath the row, in the bottom of a furrow, much greater care is required not to get results which, in effect, so far as the relations of manure to soil are concerned, are not equivalent to 30 to 50 tons per acre. In such cases, not only may normal nitrification be interfered with, but concentration of the plant roots within a small volume of soil where the plant food has been made overabundant may result in such a deficiency of soil moisture that, for this reason alone, the manure becomes comparatively inefficient.

BULLETIN "F."

The Movement of Water-soluble Salts in Soils.

In investigating the amounts of water-soluble salts in and their absorption by different soil types in reference to their bearing upon problems in soil management, it was necessary to take into consideration, also, the movements of these salts as determined by diffusion, gravitation and capillarity.

It is now well recognized that the surface cultivation of soils, such as maintains, for intertilled crops, a loose, open texture in the upper two to four inches, very materially influences the capillary movements of the soil moisture and reduces its rate of evaporation from the surface. This being true of the soil moisture, it was to be expected that surface tillage would also exert an influence upon the movement and position of the water-soluble salts which it may carry in solution, and observations were made, both upon the capillary movement of salts through the different soil types under investigation, and regarding the influence of soil mulches upon the position in and movement of water-soluble salts in soils.

Capillary Movement of Soluble Salts in Soils.

CAPILLARY MOVEMENT IN SIX SOIL TYPES.

In the first series of observations made only the movement of the negative radicles was determined, the work being done in 1902 before the methods for the estimation of bases had been devised. Six cylinders of galvanized iron, 5¼ inches in diameter and 12 inches deep, were carefully packed with the same kind of soil, which had been taken from the surface foot in

good field moisture condition. Previous to packing, the soil was screened through a sieve of one-fourth inch meshes and, in 20-pound lots, was spread over 8 square feet of surface on a mixing floor. Over this soil was sowed 2 grams of acme guano and then a second layer of soil added, sowing fertilizer again on the top, and repeating the operation until 200 lbs. of soil had been thus treated. The whole soil was then shoveled over three times to more thoroughly incorporate the fertilizer with it. The six cylinders were then filled simultaneously, placing a cupful of soil, "struck off," into each, in regular rotation, with gentle tamping after each addition of soil, until they were all full.

At the time the soil was being placed in the cylinders a small sample from each cup was taken, with a spatula, to constitute a composite representing the condition of the soil in the several cylinders at starting.

The filled cylinders, when "struck off," weighed:

No. 1 lbs.	No. 2 lbs.	No. 3 lbs.	No. 4 lbs.	No. 5 lbs.	No. 6 lbs.
19.36	19.52	19.56	19.52	19.56	19.68

The several cylinders were provided with reservoirs at their bases which permitted the addition of water at the bottom of the column, and its rise by capillarity through the soil. When filled, they were placed side by side, as represented in Fig. 1, p. 64, at the left, and 500 c. c. of water added; when this had been absorbed, another 500 c. c. was added and the cylinders allowed to stand 24 hours. At this time the soil was removed from one of the cylinders in 2-inch sections and the water-soluble salts determined. The covers were removed from the remaining cylinders, 300 c. c. more of water added, and evaporation permitted to maintain the capillary rise of moisture through the soil during different intervals of time. Three soil types were subjected to this treatment and the results are given in the next tables, as mean values, showing the change in the relative amounts of each ingredient determined in the respective depths of soil.

FIG. 1.—Showing method of studying capillary movement of salts in different soil types, and the effect of mulches upon the distribution of salts in soils.

Mean distribution of salts in three soil types after a capillary movement during 15 to 23 days.

Depth.	NO_3.	Cl.	SO_4.	HPO_4.	HCO_3	SiO_3.
	In parts per million of dry soil.					
0 to 2 inches	278.00	202.53	267.04	8.94	8.24	3.91
2 to 4 inches	21.78	10.30	24.30	8.87	8.42	3.95
4 to 6 inches	22.03	10.96	19.93	8.93	8.72	4.41
6 to 8 inches	22.73	11.08	15.16	8.92	8.62	4.52
8 to 10 inches	23.60	9.74	9.60	8.68	9.27	4.92
10 to 12 inches	22.07	9.33	8.03	8.19	7.53	5.09
Average at close	65.04	42.32	57.34	8.76	8.47	4.47
Present at start	23.75	38.94	53.38	7.02	5.59	2.40
Difference	41.29	3.38	3.96	1.74	2.88	2.07

This table contains only the data obtained from that cylinder in each series which was subjected to the longest capillary movement. Each of the other cylinders was also examined in such a succession as to show the capillary movements of salts which had taken place at the end of intervals of different duration.

In this table it will be observed that each and every ingredient has been recovered from the soil in larger amounts than were recovered from the soil at the start and the mean differences are recorded in the last line of the table, where, it will be seen, that the excess amounts recovered range from 1.74 parts of HPO_4 per million of dry soil in a column one foot in depth to 41.29 parts per million of nitric acid (NO_3). A portion of this increase is due to salts, which were carried in 1300 c. c. of tap water, added to each cylinder to secure capillary movement and whose composition is given below. The water added was about one-fifth the dry weight of the soil.

Amounts of salts in water added to the soil.

	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_3.
	In parts per million.					
In water	.38	1.53	5.28	2.32	3.92	9.79
Added to soil	.07	.31	1.06	.46	.78	1.96

In the surface two inches of soil there has been an extremely large accumulation of nitrates, sulphates and chlorides; so, too, has there been an increase of the other three ingredients determined and, in every probability, considerable amounts of one or more of the bases which are essential plant foods. So large was this capillary concentration of the most soluble salts that only 30.8 per cent. of the total nitrates, in the foot of soil, remained below the surface two inches; only 20.6 per cent. of the chlorides and only 25.3 per cent. of the sulphates; and yet, to be serviceable to a crop, it should all remain below the surface 2 inches. The amount of water which passed by capillarity through the bottom layer of these 12 inches of soil was about 4.37 inches in depth.

It must be said that the data given in the table, p. 64, do not represent the maximum concentration which occurred in the surface 2 inches. It was the cylinders examined on the fourth or fifth dates which showed the largest accumulation of salts in the surface two inches. Later, the capillary rise had become so slow, on account of the drying out of the soils, that the backward diffusion of the very soluble salts, in several cases, espe-

cially of the chlorides, became more rapid than the forward movement due to capillarity, and the result was the salts diminished at the top after a certain relation of concentration to the rate of capillary movement had become established.

The mean rates of accumulation of the most soluble salts—chlorides, nitrates and sulphates—as shown by the examinations made on successive dates, are given in the next table, where the mean intervals of time during which capillary movement acted in effecting this distribution, are also given. In the same table are given the corresponding data for the phosphates, by way of contrast.

Mean distribution of water-soluble salts, as affected by capillarity, at the close of different intervals.

Mean time.	0–2 inches.	2–4 inches.	4–6 inches.	6–8 inches.	8–10 inches	10–12 inches.
	In parts per million of dry soil.					
	Nitrates (NO_3).					
1 day	46.43	46.93	29.48	13.12	6.68	2.59
4.3 days	127.93	24.27	17.05	11.21	6.69	2.61
7.3 days	157.33	17.09	11.74	8.59	7.06	3.46
10.3 days	163.73	17.74	13.79	11.48	9.80	7.19
15 days	181.57	16.94	16.97	16.68	15.01	15.40
19 days	278.00	21.78	22.03	22.73	23.60	22.07
	Chlorides (Cl).					
1 day	90.55	79.48	46.10	16.88	11.83	8.04
4.3 days	190.50	18.53	5.55	5.66	5.48	5.31
7.3 days	196.07	11.76	9.08	7.12	7.67	6.05
10.3 days	207.76	7.99	6.74	7.35	6.90	7.62
15 days	210.91	8.89	7.16	10.10	8.36	8.92
19 days	202.53	10.30	10.96	11.08	9.74	9.33
	Sulphates (SO_4).					
1 day	104.34	121.15	96.81	47.90	29.28	19.84
4.3 days	185.38	72.92	47.65	26.22	9.78	8.75
7.3 days	188.63	60.60	38.43	20.56	10.31	7.96
10.3 days	231.44	46.54	30.96	17.35	10.55	9.30
15 days	257.13	33.56	24.93	17.37	12.99	12.12
19 days	267.04	24.30	19.93	15.16	9.60	8.03
	Phosphates (HPO_4).					
1 day	8.66	8.49	8.75	10.10	8.67	9.22
4.3 days	8.58	8.18	8.81	8.13	9.52	10.52
7.3 days	8.88	7.85	7.92	9.12	10.88	10.54
10.3 days	8.56	8.33	8.28	9.54	10.89	10.84
15 days	10.44	9.44	9.22	9.76	10.44	11.07
19 days	8.94	8.87	8.93	8.92	8.68	8.19

From this table it will be seen that, as an average, the salts of the three soils increased in the surface layer up to the end of 19 days. This, however, was not true of two of the soils making up the average. In the bottom layer the nitrates increased, period by period, after the first day; and the same relation was true of the 8 to 10 inches. These increases are probably due to nitrification which was progressing in the soils.

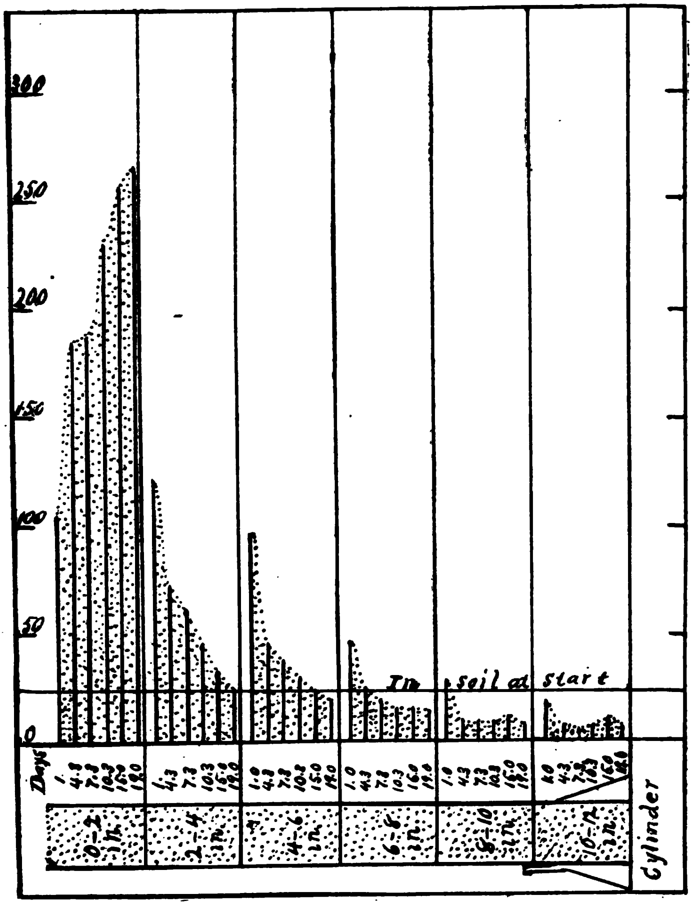

FIG. 2.—Showing the mean distribution of sulphates in three soil types resulting from capillary movement.

In the case of the chlorides there was an increase in the surface layer until the end of 15 days, when these fell off, but increased in each and every layer below the surface during the

last four days, showing a downward diffusion which exceeded the capillary rise.

The changes in sulphates, from period to period, are shown graphically in Fig. 2, p. 67, for the several depths. In this case the surface layer gained in SO_4 until the end while the bottom layer had least in it at this time, indicating that the diffusion rate was too slow to counteract the capillary rise.

In the case of the phosphates, the absorption was evidently so strong from the first that the amounts left in recoverable form were too small to bring out clearly the movements within so short a series of observations. In the next table the percentage amounts of phosphates found are given, using that recovered from the soil at the start as the basis of comparison.

Amounts of phosphates recovered in different layers, expressed in per cents.

	0-2 inches.	2-4 inches.	4-6 inches.	6-8 inches.	8-10 inches.	10-12 inches.
	In per cent. of amount at start					
In soil at start	100.0	100.0	100.0	100.0	100.0	100.0
After 1 day	123.3	120.9	124.6	144.9	123.5	131.3
After 4.3 days	122.2	116.5	125.5	116.6	135.6	149.8
After 7.3 days	126.5	111.8	112.8	129.9	155.0	150.1
After 10.3 days	121.9	118.7	117.9	135.9	155.1	154.4
After 15 days	148.7	134.5	131.3	139.0	148.7	157.7
After 19 days	127.4	126.3	127.2	127.1	123.6	116.7

The amount of phosphoric acid added to the soil with the water was only 4.4 per cent. of the amount present at the start, but the smallest amount recovered was 116.7 per cent. of that found in the soil at the start, while the largest amounts found range near 150 per cent. These differences are larger than the error of the method and indicate that more phosphoric acid has come into recoverable condition with water alone, during this capillary treatment, than existed in the soils before being so treated. It has been demonstrated, through both field and laboratory studies, that one effect of capillary movement is to concentrate nitrates to such an extent that larger amounts of them may be recovered from a soil than it is possible to recover where capillary concentration has not taken place. That this may also be true for other salts is to be expected unless it be in those cases where large absorption takes place, as so often happens with potash and phosphoric acid.

CAPILLARY CONCENTRATION OF SALTS UNDER FIELD CONDITIONS.

Field studies relating to this subject were made by the writer and Mr. J. O. Belz during the season of 1901*, which demonstrated that, under the conditions of furrow irrigation, on both a medium clay loam and on a light, sandy soil very notable movements of nitrates occur through downward, lateral and upward capillarity; and it appears from those studies that the influence of the lateral capillary sweeping of salts was great enough to be reflected in the yield of potatoes across a distance of more than 6 feet or in the third row away from the last irrigated furrow.

As an illustration of the magnitude and rapidity of the movement of nitrates in field soils, resulting from capillary action, after irrigation by the furrow method, and to show what must often take place after heavy rains where ridge and furrow cultivation is practiced, as is so generally done in many parts of the South, the following observations are cited:

IN A COARSE SANDY SOIL.

A field of potatoes, on coarse sandy land, at Stevens Point, Wis., with rows 3 feet apart and hilled, was examined for nitrates under and between the rows just before it was to be irrigated. The same rows were again examined for nitrates at different intervals after the water had been applied. Four series of observations were made upon this sandy soil and the results are given in the next table:

Concentration of nitrates by lateral capillary movement in sandy soil.

	Under Potato Rows.				Between Potato Rows.			
	1st ft.	2nd ft.	3rd ft.	4th ft.	1st ft.	2nd ft.	3rd ft.	4th ft.
	In parts per million of dry soil.							
Before irrigation	9.37	7.17	3.55	2.40	12.12	6.84	4.23	3.81
1 hour after irrigation	12.67	21.55	7.78	27.58	5.57	8.51	12.52	11.54
Change	3.30	14.38	4.23	25.18	−6.55	1.67	8.29	7.73

*United States Department of Agriculture, Office of Experiment Stations, Bulletin No. 119, p. 345.

From this table it is clear that, during the short interval of about one hour during which the water was running between the rows and another hour after the water was turned off, a very marked change had occurred in the distribution of nitrates in the soil. As soon as the water was led into the furrows percolation began and in front of the advancing water, as well as laterally from it under the rows from both sides, capillary action shoved the water, already in the soil, together with the nitrates which it carried, downward and sidewise, causing a concentration at the places where the capillary water accumulated.

IN MEDIUM CLAY LOAM.

In the next table are cited similar observations made at Madison, Wis., also in a potato field, but on a medium clay loam richer in nitrates.

Concentration of nitrates by lateral capillary movement in a medium clay loam rich in nitrates.

	UNDER POTATO ROWS.				BETWEEN POTATO ROWS.			
	1st ft.	2nd ft.	3rd ft.	4th ft.	1st ft.	2nd ft.	3rd ft.	4th ft.
	In parts per million of dry soil.							
Before irrigation	248.26	21.75	6.29	5.80	51.09	34.45	26.60	9.73
4 hours after irrigation	294.80	41.71	11.53	23.04	29.68	35.33	18.90	8.52
Change	46.54	19.96	5.24	17.24	−21.41	.88	−7.70	−1.21
Before irrigation	248.26	21.75	6.29	5.80	51.09	34.45	26.60	9.73
26 hours after irrigation	303.92	14.90	10.03	4.77	31.02	40.80	26.80	7.93
Change	55.66	−6.85	3.74	−1.03	−20.07	6.35	.20	−1.80
Before irrigation	248.26	21.75	6.29	5.80	51.09	34.45	26.60	9.73
50 hours after irrigation	349.26	114.84	10.74	5.42	33.42	32.64	21.06	7.20
Change	101.00	93.09	4.45	−.38	−17.67	−1.81	−5.54	−2.53

In all of these series, the determinations were made upon composite samples of 4 cores, each taken within 10 to 12 inches of the place where the ones of the preceding series were taken. In the first group of the table the interval of time between the taking of the two sets of samples is too short to admit of either nitrification or denitrification having occurred to such an extent

as to cause the differences observed. Time enough did, however, intervene between the start and the last series to permit considerable changes of a biological character to take place; but the associated changes which were observed to have occurred, in the water content of the soils, were usually in the direction which would explain the observed changes in the amounts of nitrates had they resulted from translocation by capillarity.

IN NORFOLK SANDY SOIL.

A field on the Norfolk Sandy Soil had been planted to peas the latter part of January, 1902, in rows 3.5 feet apart, under which had been applied 500 lbs. of guano together with stable manure at the rate of 50 bushels per acre, both drilled in the furrows before planting. The fertilizer applied carried the manufacturer's guarantee to contain 5 per cent. potash, 5 per cent. ammonia, and 8 per cent. of phosphoric acid. In 1901 this field had been given an application of guano, drilled under cotton rows, at the rate of 1,000 lbs. per acre.

On May 5, just as the peas were approaching the stage of maturity for picking, samples of soil were taken, in one-foot sections, to a depth of four feet, both under and between the rows; the cores of the respective composites being taken in pairs immediately adjacent, one under and the other between the rows. Two sets of these samples were taken at this time, one where the peas were large and vigorous and the other where they were smaller. In the next table are given the results found.

Water-soluble salts under and between fertilized rows of peas.

Rows.	Under Good Peas.				Under Poor Peas.			
	1st ft.	2nd ft.	3rd ft.	4th ft.	1st ft.	2nd ft	3rd ft.	4th ft.
	In parts per million of dry soil.							
	Amounts of nitrates (NO_3).							
Under	8.16	4.70	4.68	4.34	4.76	3.28	3.25	3.81
Between	3.86	2.42	2.54	5.54	3.33	2.24	3.05	3.51
Difference	4.30	2.28	2.14	−1.20	1.43	1.04	.20	.30
	Amounts of phosphates (HPO_4).							
Under	11.34	7.91	5.37	5.30	8.01	5.16	3.88	3.83
Between	9.35	6.62	4.66	4.54	5.83	5.23	3.88	2.99
Difference	1.99	1.29	.71	.76	2.18	−.07	0.00	.84
	Amounts of sulphates (SO_4).							
Under	48.88	31.42	34.58	34.13	3.08	11.44	37.23	14.93
Between	32.85	22.87	30.66	33.91	2.05	20.01	33.91	12.64
Difference	16.03	8.55	3.92	.22	1.03	−8.57	3.32	2.29
	Amounts of bicarbonates (HCO_3).							
Under	12.68	12.92	13.69	13.62	12.97	13.17	17.40	13.69
Between	16.00	13.17	10.39	13.55	12.97	10.09	10.39	16.79
Difference	−3.32	−.25	3.30	.07	00.00	3.08	7.01	−3.10
	Amounts of chlorides (Cl).							
Under	18.41	22.55	11.92	19.78	18.87	19.13	16.18	11.93
Between	11.25	15.32	8.08	15.74	15.09	15.64	12.09	11.73
Difference	7.16	7.23	3.84	4.04	3.78	3.49	4.09	.20
	Amounts of silicates (SiO_3).							
Under	1.36	3.13	5.16	4.39	2.09	3.19	5.62	5.53
Between	.35	2.48	5.29	4.74	2.09	4.35	6.35	5.43
Difference	1.01	.65	−.13	−.35	0.00	−1.16	−.73	.10

On this field, as is the practice generally for intertilled crops here, ridge and furrow cultivation was practiced. The data of the table show that there is an unequal distribution of readily water-soluble salts in this field, which extends even into the 4th foot. On account of the method of applying the fertilizers under the row it is to be expected, even so long after the treatment as was the case here, that a difference would obtain in the direction observed, so far as the first foot and, perhaps,

even the second foot is concerned. So, too, if it had transpired that a heavy rain fell, before the rows had been ridged, and especially while they were depressed after applying the fertilizer, the more soluble salts and those less strongly absorbed by the soil might have been carried by percolation into the third and fourth feet, so as to have developed differences at these levels. It appears highly probable, however, that differences due only to such a cause would have been obliterated by lateral diffusion before the date of collecting the samples.

The more probable explanation of the observed differences is that they had been developed, partly as stated, but also as the result of heavier percolation between the rows after rainfalls and the capillary sweeping which followed. The rainfall records show that on April 29, 30 and May 2, rain fell to the extent of .35, .20 and .16 inches, respectively, the latter occurring only 3 days prior to taking the samples. With the ridged condition of the surface and the generally level nature of the field, a rapid fall of rain does have the effect of sometimes throwing into the furrows the equivalent of 2 or 3 times the amounts of water indicated by the rainfall observed, and in this way may have established such conditions as are associated with furrow irrigation, whose effects upon the movement of nitrates have been cited.

The table shows that, except in the case of the silica, and perhaps the bicarbonates, the distribution of salts is such as would be expected from furrow irrigation, and it appears more probable that the differences are due to such an effect rather than that the salts have either percolated or diffused directly downward from the furrow where the fertilizers were applied.

ON GOLDSBORO COMPACT SANDY LOAM AND SELMA SILT LOAM.

In two other cases similar comparisons were made on samples taken under and between rows of peas, one on the Goldsboro Compact Sandy Loam and the other upon the Selma Silt Loam. Both crops were planted the last of January, the 24th and 25th. Under the pea rows, on the former soil, were applied 400 lbs. of guano and 25 bushels of cotton seed per acre;

under the latter 400 lbs. of guano per acre. To the latter there was also applied 625 bushels per acre of a compost made from one part of yard manure and one of soil, spread broadcast and plowed in. The following table gives a portion of the data determined May 2nd and 3rd.

Water-soluble salts under and between rows of peas.

	On Goldsboro Compact Sandy Loam.				On Selma Silt Loam.			
	1st ft.	2nd ft	3d ft.	4th ft.	1st ft.	2nd ft.	3d ft.	4th ft.
	In parts per million of dry soil.							
	Amounts of nitrates (NO_3).							
Under rows	7.60	7.82	8.22	11.60	34.00	21.60	21.50	15.50
Between rows	8.80	4.60	4.92	17.50	25.70	22.80	21.50	14.90
Difference	−1.20	3.22	3.32	−5.90	8.30	−1.23	00.00	.60
	Amounts of phosphates (HPO_4).							
Under rows	10.63	4.60	6.29	6.38	8.54	7.28	6.47	5.98
Between rows	8.01	3.80	6.29	7.07	7.38	6.65	6.06	5.06
Difference	2.62	.80	0.00	−.69	1.16	.63	.41	.92
	Amounts of sulphates (SO_4).							
Under rows	24.97	31.34	31.07	3.37	50.36	31.92	9.56	8.43
Between rows	2.05	17.19	28.77	3.33	23.11	19.94	11.00	5.94
Difference	22.92	14.15	2.30	.04	27.25	11.98	−1.44	2.49

In these cases the differences are not as strongly marked throughout the four feet as they were in the former series, but there can be little doubt but that either the fertilizer has advanced downward directly beneath the rows or else there has been lateral capillary sweeping of salts which has caused the concentration under the rows.

CAPILLARY MOVEMENT OF SALTS IN EIGHT SOIL TYPES.

METHOD OF TREATMENT.

In these studies a pair of the 2-foot cylinders represented in Fig. 1, p. 64, were filled, at each station, with the soil of the surface foot of each type, in a nearly air-dry condition. The

soil used was collected from the immediate surface of the unfertilized sub-plots and packed in the cylinders in the normal crumb-structure condition.

To study the effect of the different soils upon the capillary movement of salts a bulk lot of solution was prepared at the central laboratory and shipped in glass-stoppered bottles to the stations. This solution as used was found, by the colorimetric methods, to contain the different ingredients in amounts as stated in the following table:

Composition of solution used in capillary movement of salts in soils.

K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
In parts per million of solution.								
119.54	30.00	41.80	55.65	49.95	162.66	143.50	24.17	9.95

The solution was added to the reservoirs of the two cylinders of both pairs at the same time, as rapidly as capillarity would permit, until the soils became wet on the surface, the covers being kept on to prevent evaporation. At about this time the soil was removed from one of the cylinders in one- or two-inch layers, as indicated in the tables beyond, weighed and dried and the per cent. of moisture determined. The other cylinder of soil had its cover removed and was set out in a free circulation of air, to strengthen the loss of water by evaporation and distilled water was kept supplied until about as much had been added to the soil as it had taken of the salt solution. There are thus two series of soil samples: (1) one through which a salt solution had risen by capillarity until the soil was wet on the surface, and, (2) another in which distilled water was permitted to follow, also by capillarity, the salt solution until enough more had entered the soil to have about displaced the salt solution. Through a misunderstanding, these conditions were not fully realized in all cases, as will appear in the next section.

AMOUNT OF CAPILLARY MOVEMENT.

The amount of capillary movement which took place in each cylinder will be indicated by the amounts of solution and of distilled water which were added in each case, and these are given in the next table.

Amounts of solution and of distilled water added to each soil.

	Norfolk Sandy Soil.	Selma Silt Loam.	Norfolk Sand.	Sassafras Sandy Loam.	Hagerst'wn Clay Loam.	Hagerst'wn Loam.	Janesville Loam.	Miami Loam.
	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.
No. 1. Solution added...	2330	2260	2309	2270	2300	2400	2445	2165
No. 2. Solution added...	2366	2248	2097	2127	2400	2400	2481	2262
No. 2. Disti'ed w'ter add	652	518	750	1039	2350	2400	2505	2227

The amount of solution which passed into the soil of each cylinder is thus something more than two liters. In the Janesville and Lancaster soils to which distilled water was added there was applied as much more; but the other four soils received less.

It must be understood, in considering the results obtained, that the conditions of the experiment were such that the lower section of each soil column had practically been washed with a salt solution, while the upper section in each case had had a salt solution added to it by capillarity, the solution rising into it from the layers below. In addition to this, the bottom layer of the second cylinder of each pair, had been washed with a certain amount of distilled water passing upward through it.

DURATION OF CAPILLARY MOVEMENT.

The Norfolk Sandy Soil and Selma Silt Loam, which received only the salt solution, were under the conditions of capillary movement during 20 days; while the cylinders receiving the distilled water were under these conditions 51 days.

The Norfolk Sand and Sassafras Sandy Loam were under the conditions of capillary movement during 19 days, where no distilled water was added, and during 50 days where it was

added, the soil being removed 7 days after the last distilled water had been introduced.

In the case of the Lancaster soils the salt solution was added to all cylinders between July 12 and 19, and the soils were removed from the ones to which no distilled water had been given, on the 29th, making a capillary period of 17 days. Distilled water was introduced between July 28 and August 24 and the soil was removed on August 31, making a capillary period of 50 days for the second pair of cylinders.

At Janesville the solutions were added to the soils between July 11 and 15, and the distilled water between July 27 and August 29. The cylinders receiving the solution had the soil removed on July 29, making the period of capillary movement 18 days. The soil was removed from the distilled water pair on September 1, making this period 52 days.

WATER-SOLUBLE SALTS RECOVERED AFTER CAPILLARY MOVEMENT.

At the close of the period of capillary movement, in each case, the soil was removed in consecutive layers, the first four, one inch each, and the balance, two inches deep. At Upper Marlboro the soil was not sufficiently firmed to prevent settling when the water was added, with the result that the columns were shortened by shrinkage the amounts indicated in the tables which follow, where the amounts of salts found at the several depths in the different soils and under the different conditions are given.

Distribution of water-soluble salts resulting from capillarity.

Depth. Inches.	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million of dry soil.								
	Norfolk Sandy Soil.								
	After a period of 20 days.								
0—1	100.00	1312.5	269.12	1004.80	2.6	200.0	—30	135	2.9
1—2	21.68	187.5	25.93	181.20	3.0	97.5	—10	5	3.3
2—3	18.50	103.1	15.22	100.80	3.3	95.0	—10	0	3.6
3—4	17.12	62.5	13.98	53.40	3.9	95.0	—6	0	4.1
4—6	17.76	40.0	13.17	16.52	4.1	92.5	—2	0	4.5
6—8	13.20	40.0	11.41	10.68	4.3	95.0	0	0	4.2
8—10	12.84	37.5	10.07	7.72	4.2	90.0	4	0	5.2
10-12	12.04	41.3	9.26	10.08	4.8	92.5	4	0	5.5
12—14	12.52	35.0	9.01	8.26	5.3	92.5	2	0	5.4
14—16	12.20	37.5	9.26	10.38	5.4	90.0	4	0	4.9
16—18	9.56	42.5	11.04	7.26	4.5	95.0	6	0	5.7
18—20	10.84	48.8	9.01	10.68	3.9	92.5	6	0	4.6
20—22	13.00	13.5	8.40	5.68	5.4	4.0	8	0	4.9
22—24	43.36	4.5	9.01	5.50	7.7	9.0	14	0	7.1
In soil at start	17.12	110.0	16.79	103.80	3.8	55.0	4	0	4.4
	After a period of 51 days.								
0—1	152.40	1150.0	273.92	1620.00	3.3	437.5	—4	170	4.9
1—2	13.92	75.5	11.61	33.76	4.7	160.0	4	0	5.3
2—3	12.68	28.8	11.04	16.16	4.2	120.0	2	0	4.9
3—4	15.48	28.5	11.04	19.12	3.9	115.0	0	0	5.0
4—6	13.00	29.0	10.37	21.36	3.9	115.0	4	0	4.8
6—8	15.00	29.0	10.37	17.28	4.9	112.5	8	0	5.2
8—10	13.36	29.0	10.07	18.16	4.3	90.0	8	0	5.1
10—12	13.72	29.5	11.04	22.72	4.0	92.5	2	0	5.1
12—14	13.72	30.5	11.41	24.20	4.7	92.5	8	0	5.3
14—16	14.36	30.5	10.87	19.64	4.5	100.0	0	0	5.2
16—18	12.52	30.0	10.37	10.38	4.1	95.0	4	0	4.9
18—20	13.72	29.0	10.07	5.04	4.4	80.0	2	0	5.6
20—22	22.16	23.0	9.93	3.49	4.8	37.5	21	0	5.3
22—24	30.96	16.0	10.37	3.95	6.2	21.0	23	0	6.0
In soil at start	17.12	110.0	16.79	103.80	3.8	55.0	4	0	4.4
	Selma Silt Loam.								
	After a period of 20 days.								
0-1	65.00	2125.0	273.92	3632.0	3.3	375.0	—18	145	4.1
1-2	31.52	487.5	41.78	1068.0	4.5	210.0	—16	45	4.6
2-3	24.40	450.0	27.61	908.0	5.0	160.0	—12	25	4.8
3-4	20.32	437.5	23.46	726.0	5.2	150.0	—14	20	4.9
4-6	15.48	400.0	21.39	466.0	5.5	170.0	—8	10	5.0
6-8	12.36	262.5	15.92	196.4	6.0	180.0	0	0	5.4
8-10	12.84	120.0	12.03	86.5	6.5	190.0	4	0	5.8
10-12	10.88	90.0	11.61	58.6	7.1	175.0	2	0	6.5
12-14	8.42	75.0	11.41	47.8	7.3	130.0	2	0	7.0
14-16	8.28	75.0	11.41	37.1	7.1	130.0	10	0	7.1
16-18	6.86	75.0	11.80	34.6	7.2	160.0	10	0	7.2
18-20	6.36	90.0	11.22	10.38	7.6	175.0	10	0	6.6
20-22	46.48	85.0	8.78	3.03	7.5	180.0	16	0	6.8
22-24	46.00	23.0	8.56	3.63	10.0	115.0	40	0	9.0
In soil at start	16.84	450.0	15.56	201.60	4.9	95.00	—8	5	5.2
	After a period of 51 days.								
0-1	130.00	4500.0	342.40	2968.0	3.0	337.5	—5	295	4.0
1-2	18.08	312.5	26.34	346.0	3.7	122.5	—6	15	5.4
2-3	17.12	250.0	19.02	279.2	4.2	105.0	—8	0	5.6
3-4	13.92	206.3	17.57	201.6	4.9	115.0	—4	0	5.8
4-6	11.08	156.3	13.70	201.6	5.1	130.0	—2	0	6.2
6-8	10.60	112.5	12.94	53.4	5.7	122.5	—2	0	7.0
8-10	8.56	100.0	11.80	41.3	6.2	105.0	—2	0	7.5
10-12	7.18	92.5	10.70	31.6	6.6	102.5	—2	0	7.7
12-14	7.74	90.0	9.78	24.2	7.2	95.0	—2	0	8.2
14 16	8.28	90.0	11.04	26.92	7.9	95.0	2	0	8.2
16-18	7.88	92.5	9.51	20.16	8.0	97.5	2	0	8.3
18-20	8.28	87.5	9.51	8.26	7.0	90.0	0	5	7.7
20 22	21.68	70.0	8.40	5.68	8.0	40.0	20	0	8.3
22-24	28.24	23.0	10.70	5.68	8.8	14.0	26	0	9.0
In soil at start	16.84	450.0	15.56	201.60	4.9	95.00	—8	5	5.2

Distribution of water-soluble salts resulting from capillarity.

Depth. Inches.	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million of dry soil.								
	Norfolk Sand.								
	After a period of 19 days.								
0- 1	31.52	300.0	63.42	1068.0	4.8	34	12	45	4.7
1- 2	15.48	45.0	18.01	145.2	4.4	34	28	0	5.3
2- 3	15.24	42.0	15.92	145.2	4.3	30	28	0	5.5
3- 4	14.36	38.5	15.56	117.2	4.3	30	32	0	4.9
4- 6	13.00	34.0	13.70	100.8	4.1	30	32	0	5.1
6- 8	11.48	32.5	12.45	69.12	4.5	33	32	0	5.5
8-10	8.72	29.0	11.61	51.92	4.3	36	36	0	5.6
10-12	8.56	26.0	10.37	43.36	4.3	36	38	0	5.5
12 14	10.00	21.0	10.37	38.24	4.9	44	40	0	5.1
14-16	10.60	21.0	12.68	31.60	4.5	86	38	0	5.3
16-18	10.60	19.0	11.61	29.04	4.4	82	42	0	5.3
18-20	14.56	18.0	11.61	9.82	5.1	80	42	0	5.5
20-22	22.72	17.0	12.03	2.59	5.1	80	52	0	5.5
22-24	38.24	14.0	12.03	2.75	4.8	74	82	0	5.3
In soil at start	15.48	15.0	11.80	46.60	3.7	40	24	0	4.7
	After a period of 50 days.								
0- 1	36.80	320.0	59.02	982.0	4.02	50	8	55	4.3
1- 2	17.12	72.0	21.14	316.0	4.3	28	18	0	4.7
2- 3	12.20	52.0	13.17	103.8	3.96	27	22	0	4.8
3- 5	10.60	46.0	11.61	72.6	3.91	27	22	0	5.1
5- 7	10.00	30.0	10.54	50.4	4.5	28	26	0	4.5
7- 9	9.38	29.0	10.37	44.0	3.9	30	26	0	4.1
9-11	6.86	25.0	10.07	44.0	4.2	30	26	0	5.0
11-13	6.96	22.0	9.51	36.32	4.2	32	26	0	4.7
13-15	7.50	21.0	9.26	24.20	4.1	41	26	0	5.1
15-17	9.56	20.0	10.07	15.80	3.96	74	26	0	4.8
17-19	11.08	20.0	10.54	3.13	3.8	80	30	0	4.5
19-21	19.52	17.0	10.37	2.02	4.2	64	48	0	4.9
21-23	28.72	13.0	10.07	1.82	3.9	60	30	0	4.9
In soil at start	15.48	15.0	11.80	46.60	3.7	40	24	0	4.7
	Sassafras Sandy Loam.								
	After a period of 19 days.								
0- 1	45.44	380	58.04	1252.0	5.5	26	16	265	5.6
1- 2	21.68	140	21.70	395.0	6.0	26	18	85	5.7
2- 3	18.76	98	20.14	324.5	5.3	26	18	65	5.8
3- 5	13.36	80	16.79	245.5	5.6	27	30	10	5.8
5- 7	10.40	64	13.98	133.5	5.7	36	32	0	5.7
7- 9	9.56	54	12.68	84.44	6.0	48	32	0	5.8
9-11	9.20	46	12.68	70.88	5.5	50	34	0	6.1
11-13	7.06	38	12.03	51.92	6.2	54	34	0	5.7
13-15	6.42	36	11.61	50.40	6.0	68	34	0	5.9
15-17	6.34	36	11.61	39.28	5.6	86	34	0	5.8
17-19	10.00	30	11.04	22.72	5.5	89	38	0	5.8
19-21	14.36	26	10.87	9.08	6.0	144	42	0	5.8
21-23	30.46	19	11.04	2.02	5.2	128	90	0	6.1
In soil at start	9.38	36	11.41	90.80	5.1	25	26	10	5.8
	After a period of 50 days.								
0- 1	61.00	700	244.56	3028.0	4.5	23	6	530	4.3
1- 2	22.96	187.5	24.45	413.0	4.4	24	8	60	4.9
2- 3	10.84	108	14.89	207.6	4.5	29	12	20	5.0
3- 5	9.56	64	12.03	139.6	4.6	31	18	0	4.8
5- 7	8.56	52	11.04	88.6	4.4	32	20	0	5.1
7- 9	7.18	39	10.07	75.7	5.0	35	18	0	4.9
9-11	5.88	36	9.65	58.1	4.8	38	18	0	5.1
11-13	5.48	33	9.78	51.9	5.1	45	20	0	5.0
13-15	5.44	31	10.70	44.0	4.9	60	24	0	5.3
15-17	4.64	29	11.04	40.32	5.0	66	24	0	4.7
17-19	6.10	28	10.54	25.04	4.7	88	26	0	4.7
19-21	17.44	26	10.37	2.93	4.7	77	38	0	4.9
21-23	25.68	17.25	10.70	2.93	5.4	50	120	0	5.3
In soil at start	9.38	36	11.41	90.80	5.1	25	26	10	5.8

Distribution of water-soluble salts due to capillarity.

Depth. Inches.	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million of dry soil.								
	Hagerstown Clay Loam.								
	After a period of 17 days.								
0- 1	28.72	550	155.60	1730.0	9.3	168	78	85	9.4
1- 2	27.84	350	103.72	1100.0	10.1	200	95	40	10.7
2- 3	22.16	262.5	74.44	908.0	10.4	216	100	35	10.4
3- 4	20.80	237.5	67.28	605.0	10.0	216	100	20	10.5
4- 6	18.76	209.4	56.12	519.0	10.2	224	100	20	10.6
6- 8	16.56	187.5	53.48	323.2	11.2	224	120	10	11.1
8-10	15.24	140.0	41.78	165.2	10.6	224	130	0	10.2
10-12	15.00	108.0	41.78	145.2	10.3	228	130	0	10.8
12-14	18.40	108.0	45.64	100.8	10.5	248	145	0	10.5
14-16	18.76	108.0	47.54	90.8	10.7	272	145	0	11.0
16-18	19.52	100.0	55.22	72.6	12.9	312	155	0	11.7
18-20	20.80	100.0	48.24	79.0	11.3	270	155	0	10.7
20-22	21.68	100.0	35.68	86.5	9.9	170	145	0	10.3
22-24	51.36	79.0	29.02	82.6	10.7	165	140	0	10.5
In soil at start	13.20	116.0	33.64	234.4	9.9	75	135	0	14.9
	After a period of 50 days.								
0- 1	32.56	1500	503.40	3928.0	10.6	430	90	240	11.7
1- 2	24.40	170	55.22	302.8	13.0	320	143	0	12.7
2- 3	21.20	150	48.90	165.2	13.5	260	160	0	12.9
3- 4	20.00	150	48.24	151.4	13.6	250	160	0	12.5
4- 6	19.52	142.5	45.04	158.0	13.3	230	155	0	12.3
6- 8	19.12	140	43.40	106.8	13.9	230	165	0	12.8
8-10	19.12	132	38.90	110.0	13.9	200	160	0	12.9
10-12	18.76	120	35.68	63.2	13.6	160	160	0	13.0
12-14	17.76	112	35.68	67.3	13.2	155	165	0	12.9
14-16	17.44	110	34.94	41.3	13.0	150	170	0	13.6
16-18	22.16	110	33.64	9.56	12.9	150	185	0	12.5
18-20	22.72	90	32.92	3.25	12.7	142.5	185	0	12.1
20-22	25.16	76	25.93	11.72	12.8	125	195	0	12.5
22-24	43.36	62	23.77	8.08	11.4	112.5	170	0	11.5
In soil at start	13.20	116	33.64	234.4	9.9	75	135	0	14.9
	Hagerstown Loam.								
	After a period of 17 days.								
0- 1	88.80	680	236.08	2424	7.2	160	42	74	7.4
1- 2	77.40	520	232.16	1864	6.9	128	44	74	7.4
2- 3	72.80	350	106.96	1346	5.8	104	53	35	6.5
3- 4	58.60	310	93.84	966	5.9	120	50	20	6.5
4- 6	50.00	260	51.86	550	5.6	120	61	16	6.4
6- 8	45.20	128	46.28	245.5	7.5	180	64	0	7.4
8-10	42.80	125	43.90	158.0	8.0	208	62	0	8.5
10-12	41.40	120	54.34	108.0	8.7	310	73	0	8.9
12-14	38.10	107.5	32.92	125.2	7.0	240	66	0	7.3
14-16	37.50	100	28.52	95.6	5.8	220	66	0	6.5
16-18	42.10	106	36.42	95.6	6.8	220	68	0	7.2
18-20	46.00	95	34.94	95.6	7.0	205	70	0	7.3
20-22	52.00	82.5	35.68	90.8	7.2	200	66	0	7.6
22-24	54.20	75	35.68	93.2	7.1	200	66	0	7.7
In soil at start	45.20	72.5	31.71	316.0	6.7	112	52	0	7.5
	After a period of 50 days.								
0- 1	125.80	1350	489.00	6628	7.0	232	46	185	7.6
1- 2	106.00	375	92.56	1252	8.9	224	68	37.5	8.2
2- 3	75.00	163.5	44.44	227	8.9	218.4	90	0	8.2
3- 4	66.80	160	38.90	175	8.6	216	106	0	8.3
4- 6	58.80	114.5	36.92	133	8.8	192	112	0	8.0
6- 8	56.80	108	34.24	80.64	8.6	188	114	0	8.6
8-10	55.40	93.8	31.12	55.84	9.3	208.8	133	0	8.8
10-12	55.40	90	31.12	50.08	9.2	211	135	0	9.0
12-14	55.40	90	30.57	9.56	9.4	203.5	140	0	8.8
14-16	55.40	85	32.92	9.82	9.6	202	145	0	8.7
16-18	55.40	80.75	32.92	8.64	8.2	200	140	0	8.4
18-20	56.80	79	38.04	11.36	8.0	200	140	0	8.3
20-22	95.60	75	41.98	10.68	7.9	190	150	0	8.0
22-24	113.60	73	47.54	19.64	8.3	178	140	0	8.1
In soil at start	45.20	72.5	31.71	316.00	6.7	112	52	0	7.5

Distribution of water-soluble salts due to capillarity.

Depth. Inches.	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million of dry soil.								
	Janesville Loam.								
	After a period of 18 days.								
0- 1	19.12	640	190.16	2344.00	14.54	88	8	25	13.8
1- 2	11.76	250	64.72	646.40	14.32	96	22	0	14.1
2- 3	8.42	150	52.68	675.20	16.14	96	22	0	14.9
3- 4	7.28	145	98.90	539.20	15.98	96	24	0	13.2
4- 6	6.68	126	42.80	363.20	15.76	104	28	0	14.4
6- 8	6.34	84	26.74	177.20	16.87	112	28	0	14.8
8-10	4.64	58	25.17	110.00	16.44	122	30	0	14.9
10-12	3.26	54	25.60	80.80	16.17	124	36	0	19.7
12-14	3.71	51	24.45	64.90	17.40	136	44	0	15.1
14-16	5.14	51	24.45	58.60	18.40	160	44	0	15.6
16-18	5.30	50	26.34	50.08	17.60	176	46	0	13.7
18-20	5.54	48	24.45	50.08	18.02	160	46	0	14.2
20-22	7.18	44	20.75	50.08	17.70	152	52	0	14.3
22-24	18.76	40	18.51	50.08	18.60	136	66	0	14.8
In soil at start	8.88	76	32.36	196.40	11.30	146	26	0	14.9
	After a period of 52 days.								
0- 1	34.88	925	441.76	4910.00	15.4	370	8	85	17.1
1- 2	11.48	145	38.90	240.00	17.6	162.5	16	0	20.2
2- 3	11.20	110	26.34	53.40	15.6	155	26	0	18.8
3- 4	9.64	52	24.93	8.16	18.4	150	26	0	20.0
4- 6	8.14	50	25.60	5.16	15.0	150	30	0	18.8
6- 8	7.50	50	25.60	3.82	16.5	150	32	0	19.4
8-10	6.86	45	27.61	5.19	16.6	148	44	0	19.3
10-12	6.10	44	25.60	3.63	15.0	148	44	0	18.7
12-14	5.88	40	23.77	3.13	16.6	132	52	0	19.1
14-16	7.88	37.5	22.09	2.84	15.3	102	56	0	17.8
16-18	8.72	34	21.39	3.95	15.6	100	58	0	17.2
18-20	9.56	34	19.02	3.49	16.2	83	66	0	17.8
20-22	11.08	33	19.02	3.49	15.8	16	68	0	16.5
22-24	23.84	33	17.57	3.95	14.8	9	82	0	15.4
In soil at start	8.88	76	32.36	196.40	11.3	146	26	0	14.9
	Miami Loam.								
	After a period of 18 days.								
0- 1	48.80	1000	297.76	3370.0	12.2	76	14	25	15.8
1- 2	20.80	237.5	60.16	638.0	13.9	76	22	0	16.5
2- 3	16.00	170	48.90	534.0	14.2	80	26	0	16.0
3- 4	14.80	165	46.28	454.0	13.0	80	30	0	15.6
4- 6	13.36	145	38.04	302.5	12.8	84	30	0	15.0
6- 8	7.74	128	29.51	132.0	13.4	92	30	0	16.5
8-10	7.18	112.	24.82	100.8	13.6	92	42	0	16.6
10-12	6.34	92.5	26.34	79.0	13.4	100	42	0	16.4
12-14	10.84	85	23.14	56.8	11.9	112	42	0	16.0
14-16	11.36	85	25.17	51.9	12.6	140	44	0	14.7
16-18	11.36	77.5	23.77	49.1	12.1	164	44	0	14.9
18-20	11.62	71.25	22.52	42.2	12.2	112	44	0	15.2
20-22	12.58	64.0	21.14	40.3	11.8	104	46	0	15.1
22-24	20.32	54	20.89	42.7	11.5	92	68	0	14.9
In soil at start	15.76	100	30.08	103.8	9.8	108	38	0	15.9
	After a period of 52 days.								
0- 1	85.60	1300	409.60	5192.00	11.4	210	20	95	16.2
1- 2	20.32	78	30.57	121.00	13.0	165	42	0	18.5
2- 3	11.36	60	24.45	5.86	12.5	165	46	0	18.3
3- 4	5.74	58	23.46	3.95	13.5	155	48	0	18.6
4- 6	6.02	58	21.40	4.54	12.5	150	58	0	18.7
6- 8	6.42	54	21.40	4.13	14.0	147.5	62	0	20.6
8-10	6.68	54	21.14	3.79	13.3	125	75	0	19.3
10-12	6.86	52	20.75	3.79	13.7	110	76	0	18.5
12-14	8.72	52	21.39	3.95	12.7	88	84	0	17.7
14-16	8.88	49	20.14	3.95	12.3	76	96	0	17.3
16-18	11.62	46	18.51	3.25	12.2	68	108	0	16.7
18-20	12.58	46	19.56	3.25	12.4	56	106	0	16.6
20-22	12.58	40	18.51	2.93	12.7	35	100	0	17.4
22-24	30.96	38	18.51	3.79	12.0	10	102	0	17.2
In soil at start	15.76	100	30.08	103.80	9.8	108	38	0	15.9

MOVEMENT OF POTASH BY CAPILLARITY.

Two features regarding the capillary movement of potash through the eight soils under investigation, are brought out in a striking manner by the data of the several tables of the preceding pages; these are the large amounts of potash which, in every instance, have been left in recoverable form in the soil at the lower ends and in even larger amounts at the upper ends of the soil columns. If the mean amounts of potash recovered from the different sections of the soil columns of the eight types are obtained for both capillary periods, they will appear as expressed in the table next given.

Mean amounts of potash recovered from different sections of soil columns after capillary movement has taken place.

Depth. Inches.	After 20 days.	After 50 days.
	In parts per million of dry soil.	
0- 1	53.43	82.38
1- 2	28.52	29.29
2- 3	24.54	21.45
3- 4	20.83	18.97
4- 6	18.18	16.89
6- 8	15.31	16.50
8-10	14.19	15.35
10-12	13.07	15.06
12-14	13.54	15.27
14-16	13.78	15.78
16-18	14.41	16.94
18-20	16.26	20.08
20-22	25.77	30.34
22-24	39.35	41.27
Average	22.23	25.40
From soil at start	19.62	19.62

From this table it is seen that the general tendency has been for the potash to concentrate at the bottom of the columns where the solution entered, while higher up in the soil capillarity had the effect of forcing the potash upward until it was arrested in the surface inch. The general character of this resulting distribution is more clearly brought out in the diagram, Fig. 3, p. 83, where the mean amounts found in the several layers after 20 and 50 days of capillary movement had taken place are plotted to the same scale. From these curves it will be seen that the amounts of water-soluble potash recovered from

the bottom layer was greater than at any other level except that of the surface inch, and also that at the end of 50 days more potash was recovered than was recovered at the end of 20 days. Between the 18 to 20 inch level and the 3 to 4 inch level less potash could be recovered from the soil than before the capillary movement had taken place, indicating that these layers had been washed and the potash moved on into the layers above.

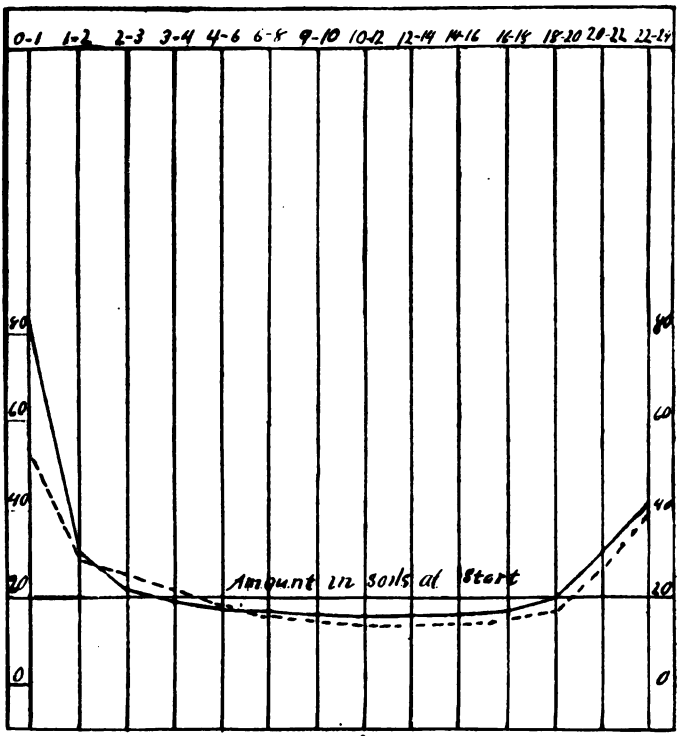

FIG. 3.—Showing distribution of water-soluble potash after capillary movement. Solid line indicates results after fifty days; broken line after 20 days. Values are means for 8 soil types.

The mean amount of potash recovered from the surface inch at the close of the 50 days was 82.38 parts per million of dry soil. Taking the mean weight of a cubic foot of soil at 73.36 lbs., as given in Bulletin "C", "Relation of Crop Yields to the Amounts of Water-Soluble Plant Food Materials Recovered from Soils," p. 51, this accummulation of potash is equivalent to about 22 lbs. per acre in the surface inch of soil.

The absolute amounts of potash recovered from the 24 inches of these eight soil types before and after capillary movement had taken place are given in the next table, expressed in pounds per acre.

Amounts of potash recovered from 24 inches of soil after capillary movement.

	Before treatment.	After 20 days.	Before treatment.	After 50 days.
	In pounds per 2 acre-feet.			
	From four poorer soils.			
Norfolk Sandy Soil	151.55	172.66	155.43	200.13
Selma Silt Loam	134.00	160.46	134.00	139.43
Norfolk Sand	118.28	116.10	116.94	100.87
Sassafras Sandy Loam	66.38	97.80	65.15	80.61
Average	117.55	136.76	117.88	130.26
	From four stronger soils.			
Hagerstown Clay Loam	92.55	155.71	92.81	161.22
Hagerstown Loam	325.76	359.59	325.01	512.71
Janesville Loam	61.97	52.38	62.30	76.40
Miami Loam	126.14	109.46	125.75	118.05
Average	151.61	169.29	151.47	217.10

From this presentation of the data it is to be observed that in but one soil, the Janesville Loam, has the absorption of the potash added to the soils been so great by them that less was recovered after 20 or after 50 days of capillary movement than was present in them, in water-soluble form, before the solution was added. In three out of four of the poorer soils, more potash was recovered after 20 days of capillary movement than after 50 days; while with the four stronger soils the reverse was the case. These relations are not unlike the case cited in Bulletin "E," "Influence of Farm Yard Manure Upon Yield and Upon the Water-Soluble Salts of Soils," p. 37, where samples of the Janesville Loam and of the Norfolk Sand were each washed by percolating 6,000 c. c. of water through them and the Janesville Loam yielded 104.62 parts per million where the Norfolk Sand yielded but 62.24, both soils having been previously treated alike with an application of manure at the rate of 200 tons per acre. It must be admitted, however, that, so

far as the evidence shows, these relations between the two groups of soils may be the result of coincidences, for in the eight soil types we have three where less salts are recovered after the longer capillary washing and five where the amounts are more, the cases, therefore, being nearly equally divided and one of the poorer soils standing in line with the stronger soils.

That capillary sweeping does have the effect of permitting more nitrates to be recovered from soils than can be secured by ordinary washing has been proven and will be referred to after discussing the effects of the capillary movement upon the other ingredients determined.

MOVEMENT OF LIME BY CAPILLARITY.

The observations of Way, Frankland and Voelcker, which have been cited in Bulletin "B," Bureau of Soils, "Amounts of Plant Food Readily Recoverable from Field Soils with Distilled Water," p. 16, show that lime passes from soils into drainage waters more abundantly than any other base, and from this relation it would be expected to be moved rapidly by capillarity also. If reference is made to the tables it will be seen that this has been the case with each and every soil type.

In the next table there are brought into comparison the amounts of potash and lime recovered from the surface layer and from the bottom layer of each soil type after 50 days of capillary movement.

Relative amounts of potash and of lime moved by capillarity which remain water-soluble.

	Norfolk Sandy Soil.	Selma Silt Loam.	Norfolk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hagerstown Loam.	Janesville Loam.	Miami Loam.
	In parts per million of dry soil.							
	Amounts accumulated in surface layer.							
Potash K..........	152.40	130.00	36.80	61.00	32.56	125.80	34.88	85.60
Lime Ca...........	1150.00	4500.00	320.00	700.00	1500.00	1350.00	925.00	1300.00
	Amounts remaining in bottom layer.							
Potash K..........	30.96	28.24	28.72	25.68	43.36	113.60	23.84	30.90
Lime Ca...........	16.00	23.00	13.00	17.25	62.00	73.00	33.00	38.06

From this table it will be seen that there is a remarkable difference between the amounts of lime and of potash recovered from the surface soil, the mean amounts for the 8 soil types being 1468 for lime and 82.38 for potash or as 18 to 1; while in the bottom layer the mean amounts recovered were 34.41 of lime to 40.67 of potash, the relations being reversed. In the language of the earlier chemists, the potash has forced the lime into solution at the bottom and maintained it there at the top.

There has been enough potash added to these soils to represent, for the entire weight, in the neighborhood of an average of 26 parts per million, and of lime 7 parts; there was present in them, before this addition, enough more to make a mean total of 43.73 of potash and 128 of lime. But at the end of 50 days of capillary movement and after rendering the soils water-free at 110° C., there was recovered from the top layers of soil a mean of 82.38 parts per million instead of 43.73 parts and from the bottom layer 40.67 parts per million, only 3 parts less; while in the case of lime the surface layer yielded an average of 1468 parts per million instead of 128 parts, and the bottom layer 34.41 parts. The capillary movement had reduced the lime which could be recovered from the bottom layer to about one-fourth and had increased that at the top 12-fold; while with the potash the decrease had been only about 6 to 7 per cent. at the bottom and the increase at the top less than 2-fold. There is thus shown a strong difference between the movement of the potash and of the lime, through these soils under the influence of capillarity.

MOVEMENT OF MAGNESIA BY CAPILLARITY.

The movements of magnesia have been, in general, more nearly analogous to those of the lime than to those of the potash, but there has been no such large accumulations in the surface inch. The relative concentrations are shown in the next table.

Relative concentrations of magnesia in the surface inch of 8 soil types.

	Before treatment.	After 20 days. At top	After 20 days. At bottom.	After 50 days. At top.	After 50 days. At bottom.
	In parts per million of dry soil.				
	Four poorer soils.				
Norfolk Sandy Soil	16.79	269.12	9.01	273.92	10.37
Selma Silt Loam	15.56	273.92	8.56	342.40	10.70
Norfolk Sand	11.80	63.42	12.03	59.02	10.07
Sassafras Sandy Loam	11.41	58.04	11.04	244.56	10.70
Average	13.89	166.13	10.16	229.98	10.46
	Four str nger soils.				
Hagerstown Clay Loam	33.64	155.60	29.02	503.40	23.77
Hagerstown Loam	31.71	236.08	35.68	489.00	47.54
Janesville Loam	32.36	190.16	18.51	441.76	17.57
Miami Loam	30.08	297.76	20.89	409.60	18.51
Average	31.95	219.90	26.03	460.94	26.85
General average	22.92	193.02	18.10	345.46	18.66

From the data of the table it is seen that the movement of magnesia into the surface inch has been enough to increase that which may be recovered by water alone to 345.46 parts per million, as an average of the 8 soil types after 50 days of capillary action. There was magnesia enough added to these soils with the solution to represent about 9 parts per million, which, added to 22.92, gives 31.92 as the amount which should be recovered from the bottom layer if no change had taken place as the result of the treatment. The mean amount which was recovered from the bottom layer was 18.66 parts per million, only a little more than one-half the amount called for with no change. The top layer of soil had increased its content of recoverable magnesia, after 50 days, about 18-fold, which is relatively more than had occurred with the lime, that increase being 12-fold.

The differences between the magnitudes of the movements of magnesia in the two groups of soils appear to be about such as would be expected from the differences in the amounts of the water-soluble magnesia which has been recovered from the untreated soils of the two groups.

The absolute amounts of magnesia which were recovered from the 24 inches of these soils are given in the next table.

Amount of magnesia recovered from 24 inches of soil after capillary movement.

	Before treatment.	After 20 days.	Before treatment.	After 50 days.
	In pounds per 2 acre-feet.			
	From four poorer soils.			
Norfolk Sandy Loam	148.63	192.44	152.43	201.74
Selma Silt Loam	123.82	205.15	123.82	206.13
Norfolk Sand	90.17	107.16	89.14	89.63
Sassafras Sandy Loam	80.75	105.60	79.24	128.15
Average	110.84	152.59	111.16	158.91
	From four stronger soils.			
Hagerstown Clay Loam	235.87	387.19	236.54	427.65
Hagerstown Loam	228.54	443.56	228.01	438.62
Janesville Loam	225.85	259.07	227.03	314.15
Miami Loam	240.76	327.19	240.00	312.95
Average	232.76	354.25	232.90	373.34

In these cases the 50 days of capillary movement have resulted in a larger accumulation of magnesia in form to be recovered with the distilled water, as was the case with the potash; the differences, however, are very small and in the case of the Hagerstown Loam and of the Miami Loam the relation is reversed.

MOVEMENT OF PHOSPHATES BY CAPILLARITY.

The tendency of nitrates to change one way or the other is so great, on account of biological influences, that the capillary movement of them cannot well be indicated by such a series of observations, except in a most general way. It will be seen from the tables of details that there had been a heavy accumulation of the nitrates in the surface layer and a large reduction of them in the lower portions of the columns, which was undoubtedly due, to a great extent, to capillary movement.

In the case of the phosphates, notwithstanding the addition of them to the soil with the solution, the absorption was so strong as to reduce the amounts which could be recovered to so

narrow a margin that the movements can be measured by the methods only with great difficulty.

There are given in the next table the mean amount of phosphates recovered from the eight soil types after the capillary periods of 20 and 50 days.

Mean amounts of phosphoric acid (HPO_4) ***recovered from different sections of soil columns after capillary movement has taken place.***

Depth in inches.	After 20 days.	After 50 days.
	In parts per million of dry soil.	
0- 1	7.18	7.41
1- 2	7.90	8.76
2- 3	8.06	8.43
3- 4	7.99	8.93
4- 6	7.97	8.44
6- 8	8.72	9.07
8 10	8.64	9.08
10-12	8.87	8.93
12-14	8.79	9.11
14-16	8.89	8.95
16-18	8.88	8.69
18-20	8.89	8.71
20 22	8.73	8.92
22-24	9.74	9.57
Average	8.52	8.79
From soil at start	6.90	6.90

From these data, there appear to be real differences between the amounts of phosphoric acid recovered at the close of the two capillary periods, but they are very small. Larger mean values are, also, found for the phosphoric acid after than before the treatment, as indeed must be expected unless complete absorption or precipitation occurs.

The probable relation of these two sets of data may be more clearly seen from the graphic representation, Fig. 4, p. 90. From this it will be seen that both curves, where they represent the conditions in the lower portions of the soil columns, show a tendency to develop the same features possessed by the potash curves in Fig. 3, p. 83. This is especially marked in the 50 day curve and the differences shown may be interpreted as indicating that, after a sufficient amount of movement, the form of the potash curve would be reproduced. In other words, there is a strong absorption of the phosphoric acid as it enters the soil but slowly it is moved forward by the water, thus reducing the amounts between and increasing that above, which

may be recovered by washing with water. These observations appear to be quite in harmony with observations on drainage waters, which show that only small amounts of phosphoric acid, relatively, escape from the soil with the water.

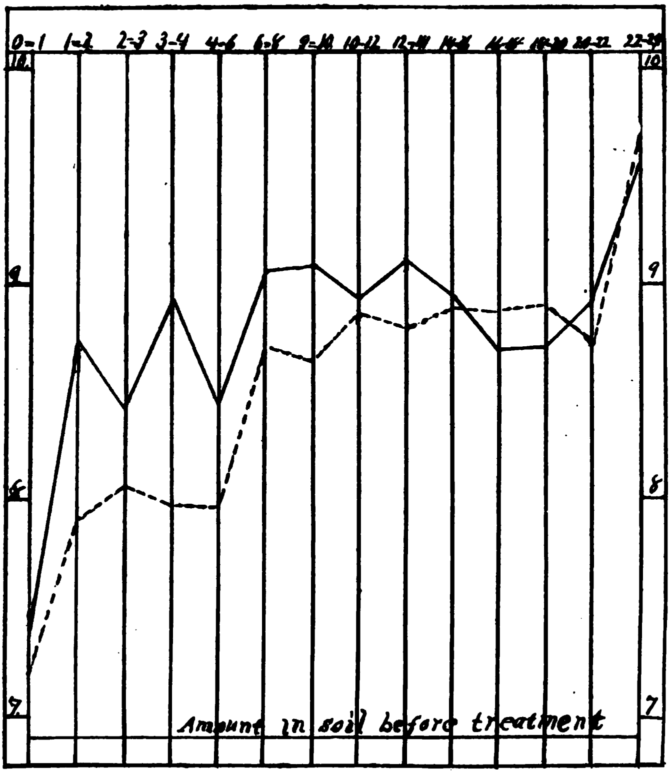

FIG. 4.—Showing distribution of water-soluble phosphates after capillary movement. Solid line indicates results after 50 days; broken line, results after 20 days. Values are means for 8 soil types.

MOVEMENTS OF SULPHATES BY CAPILLARITY.

The general tables show that, in the capillary movement of the sulphates upward through the soils, they advanced much as the lime and magnesia did, concentrating at the surface, but not as intensely as did either the chlorine or nitric acid. The Norfolk Sandy Soil increased its content of SO_4 in the surface inch nearly 4-fold in the first 20 days and nearly 8-fold in 50

days; but below the surface inch it had acquired a nearl- uniform distribution to the two lower layers, which showed so little as to appear like incorrect determinations or else large absorptions. The strength of the solution added was such that 20 per cent. of it in the soil would carry to the soil about 32 parts per million of its dry weight. The soil itself gave over to distilled water, before treatment, 55 parts per million, which added to 32 parts gives 87 parts, and this is below the amount found in nearly all except the upper and lower layers. In the column to which distilled water was added the SO_4 in the bottom layers also fell but not so low as the results found in the 20 day cylinder.

In the Selma Silt Loam, too, above the 22–24 inch layer, nearly constant amounts were recovered from the successive layers up to the 1-2 inch level, but these amounts exceed the sum of that recovered from the untreated soil and that which would be carried to the soil with the solution used, this ranging, according to the per cent. of water in the soil, from 130 to 150 parts per million of the dry soil. Indeed the solution, on its way upward through the soil, dissolved other sulphates present and to such an extent as that the amount found, at the end of 20 days of capillary movement, was equivalent to 1,362 lbs. per acre for the 24 inches of soil under treatment. If reference is made to the data of the 50 day cylinder, it will be seen that a change must have occurred before its close, whereby the sulphates which were at first liberated became again absorbed or were precipitated, from which it appears that soil solutions may undergo frequent and often radical changes as they reverse their direction of movement with changes of the water-content in the soil, and it may be reasonably expected that such changes influence the growth of crops, sometimes favorably and sometimes adversely.

In Fig. 5, p. 92, the changes, in the distribution of sulphates, which occurred in the Miami Loam, are graphically represented, and from this it appears that, during the advance of the solution through the Miami Loam, it had the effect of leaving less SO_4, in form to be recovered, at the end of 20 days than there was present in the soil to begin with in all layers, except

the 12–14 to 18–20 inches. Moreover, as time progressed and the distilled water followed the solution, forcing it upward through the soil, the sulphates were carried forward until, in the surface inch, they had increased almost as much above the normal as, at the bottom, they had fallen below it. Observa-

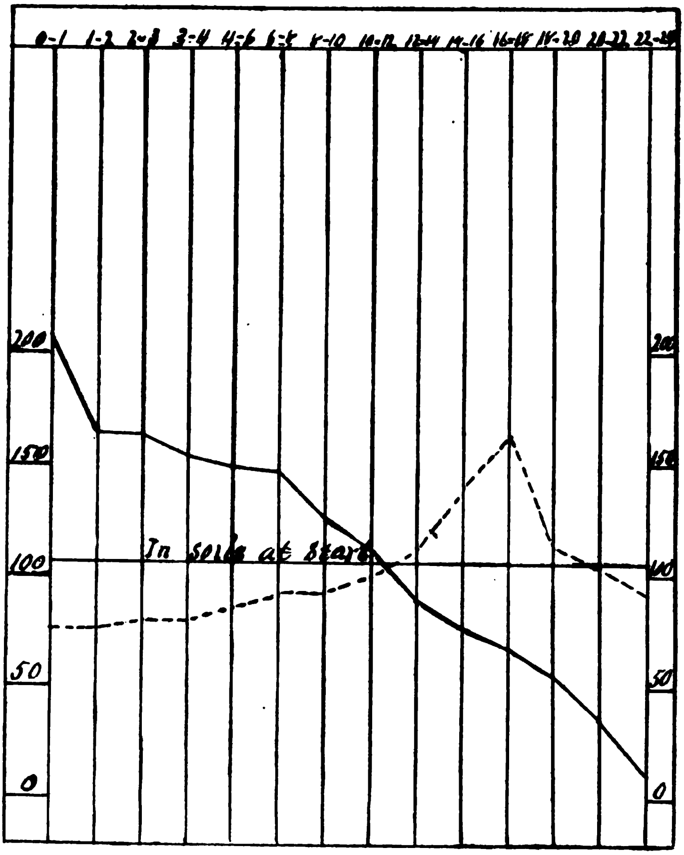

FIG. 5.—Showing distribution of water-soluble sulphates after capillary movement. Solid line indicates results after 50 days; broken line, results after 20 days. Values are means for 8 soil types.

tions like these emphasize with much force that the soluble salt content of soils is liable to suffer profound changes with the change in the character of the soil moisture and with its amount which must result from heavy rains and very drying weather, especially if at all protected, as is not infrequently the case.

MOVEMENT OF CHLORIDES BY CAPILLARITY.

No salt in the series investigated moves with such apparent freedom and abandons the soil so completely as do the chlorides, or, at least, as does the chlorine.

The most striking feature in the tables of data presented in this series of observations is the completeness with which the chlorine has disappeared from all but the surface inch of soil, in four of the types under treatment, even at the end of 20 days. This statement applies with entire fullness to the two Janesville soils and to the Norfolk Sandy Soil and the Norfolk Sand. With the Selma Silt Loam, the Sassafras Sandy Loam and the two Hagerstown Loams, the chlorine was not completely forced into the upper layer, but well up toward it.

Another point, to which special attention should be directed, is the fact that the absolute amount of chlorine recovered at the end of 50 days is greater than that which is recovered at the end of 20 days. This is doubtless partly due to the fact that the zeros in the table must be understood to mean amounts too small to measure by the method rather than no chlorine present, and the more complete capillary sweeping results in concentrating the chlorine until the quantities become large enough to be determined.

There is still another feature of these chlorine data which calls for an explanation and this is the reduction of the chlorine in the solution added to the soil, which contained 25 to 30 parts per million, to so small an amount as to fall below the limits of the method. It must be understood that the Hagerstown Loam, for example, carried in the lower two inches of soil, 30 per cent. of its dry weight of the solution, which contained not less than 24 parts per million when it entered the soil. This is enough to represent 7.2 parts per million of the dry soil could it all be recovered by the method of washing used. Moreover, it is true, in most cases, that the absolute amounts of chlorine recovered from the soils are nearly equal to, or even greater, than the amounts called for by the known amounts added to the soils with the solution plus the measured amounts in the soils before the solution was added.

It does not appear that the apparent absence of the chlorine can be explained by a failure of the method. A more probable hypothesis is that the absorption of the chlorine by the soil took place to the extent of the amount present in the solution used. If these soils contained 3, 5 or 7 parts per million more chlorine than could be recovered by the method of washing used, it is quite probable that when a solution, carrying these amounts of chlorine, is allowed to sweep the soil by capillary action, it may be able to displace a portion of that already present, and to such an extent that that which the solution carries would be absorbed sufficiently during the 20 days so that the amounts which could then be recovered by washing are too small to be measured by the methods used.

This view finds support in the retention of nitrates by soils in forms still recoverable by suitable treatment.

RECOVERY OF ABSORBED NITRIC ACID.

During the investigations relative to the movements of nitrates in soils under furrow irrigation, reported in Bulletin No. 119, Office of Experiment Stations, a series of observations was made which demonstrated that nitrates absorbed by soils may be displaced by capillary sweeping with distilled water.

When an effort was made to account for the increase of nitrates under the rows, referred to in the observations previously cited, p. 69, it was found that there was not enough nitric acid in the water added by irrigation plus that which appeared to have been lost from the soil beneath the furrows to account for the gain which had occurred beneath the rows. Moreover, the very short intervals of time during which the observed gains had taken place, together with the great depth below the surface where the increases were observed, appeared, at that time, to preclude the possibility that such additions to the soil could be made through nitrification; and it appeared that in some manner the capillary sweeping had the effect of washing the soil grains more thoroughly than was done by the method used in the laboratory and that, on this account, there resulted a con-

centration such that larger absolute amounts of nitric acid were recovered.

To test this hypothesis, two soils were procured; one a loamy sand and the other a sandy soil, each containing at the time a low per cent. of moisture. Bulk lots of both soils were screened and thoroughly mixed, so that closely duplicate samples could be obtained. Three sets of an apparatus represented in Fig. 6, p. 95, were filled with the two kinds of soil. Each piece of apparatus consisted of glass tubes, 2 inches long and seven-eighths inch inside diameter, held together with rubber tubing and closed at the lower end with a piece of muslin.

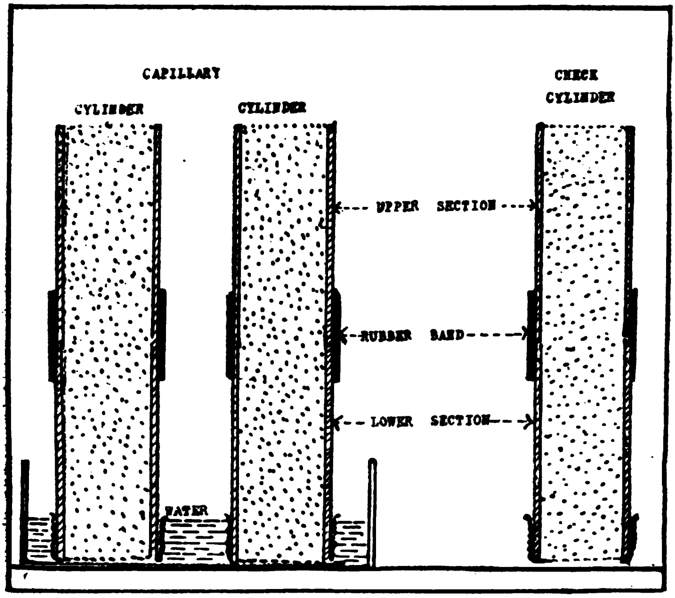

FIG. 6.—Showing apparatus used in demonstrating the possibility of recovering larger amounts of nitrates from soils by capillary sweeping than by agitation or by percolation.

When the cylinders were filled with these respective soils they were placed in nitrate-free water until, at the end of 15 minutes, the soils became moist at the surface and capillarily saturated. At this stage the two sections of the tubes were separated and the amounts of nitrates in each determined at once, obtaining the results which are given in the table which follows:

Concentration of nitrates by capillary sweeping.

	Coarse Sandy Soil.				Loamy Sand.			
	Upper section.	Check.	Lower section.	Check.	Upper section.	Check.	Lower section.	Check.
	In parts per million of dry soil.							
No. 1.. .	120.435	46.462	1.487	48.224	324.398	164.062	4.799	154.132
No. 2 ..	122.873	48.400	1.751	44.963	341.187	176.364	5.645	176.765
No. 3....	107.380	50.400	1.569	47.722	347.070	143.757	4.796	160.951
Av.....	116.896	48.421	1.602	46.970	337.552	161.394	5.080	163.949

From this table it is seen that there had been a very strong concentration of nitrates in the upper half of the soil column and if the amounts recovered from the upper and lower sections of the capillary cylinders are combined and compared with the amounts recovered from the two sections of the check cylinders, the results will appear as given in the next table:

Differences in amounts of nitrates recovered by capillary concentration and by ordinary washing.

	From Coarse Sandy Soil.		From Loamy Sand.	
	Capillary tubes.	Check tubes.	Capillary tubes	Check tubes.
	In parts per million of dry soil			
Upper section.................... ..	116.896	48.421	337.552	161.394
Lower section.	1.602	46.970	·5.080	163.949
Average...............	59.249	47.695	171.316	162.672
	47.695	47.695	162.672	162.672
Difference	11.554	00.000	8.644	000.000

It thus appears that, under the influence of capillary sweeping, it was possible to recover 24.22 per cent. more nitrates in one series and 5.31 per cent. more in the other series.

In another soil, a medium clay loam, under a bluegrass sod, which had been reduced so low in its nitric acid content by the action of the roots that only small amounts could be recovered by washing the soil in the ordinary way, capillary sweeping, by the method described, enabled solutions to be obtained which yielded an increase of 17.57 per cent. in nitrates over the ordinary method of washing, and of 23.83 per cent. in total salts as indicated by the electrical method.

RETENTION OF NITRATES BY CLEAN SAND.

In February, 1902, a sample of "Sea Island sand" in the collection of this Bureau, was rendered nitric-acid-free by repeatedly washing the dry sand in disulphonic acid and then treated with a solution of potassium nitrate. A quantity of this sand—50 grams—was washed during 3 minutes without drying, 10 consecutive times in 100 c. c. of distilled water, and the amounts of NO_3 determined in each case. After the last washing the sample was dried and the sand itself treated directly with disulphonic acid and an examination made for nitric acid. The results obtained are given in the next table:

Amounts of nitric acid recovered by repeated washing and then treating the washed sand with disulphonic acid.

Recovered with 1st washing of three minntes	3.12100 mg.
Recovered with 2nd washing of three minutes	.32840 mg.
Recovered with 3rd washing of three minutes	.04515 mg.
Recovered with 4th washing of three minutes	.01736 mg.
Recovered with 5th washing of three minutes	.01380 mg.
Recovered with 6th washing of three minutes	.01280 mg.
Recovered with 7th washing of three minutes	.01109 mg.
Recovered with 8th washing of three minutes	.01100 mg.
Recovered with 9th washing of three minutes	.01100 mg.
Recovered with 10th washing of three minutes	.01101 mg.
Recovered with disulphonic acid after drying	.76290 mg.
Total recovered	4.34551 mg.
Amount present	4.12500 mg.

These and the previous observations point strongly to the retention of nitric acid in some manner by soils, and indicate that the close and slowly moving layers of water which move over the surfaces of soil grains and granules by capillarity are able to wash them more thoroughly than is practicable by simple agitation in water or by the percolation of water through them.

The larger amount of nitric acid, recovered by the repeated washing, may be due simply to the failure of agreement between duplicate determinations on samples taken from the same bulk lot; it may be in part due to the *very* slight color which the disulphonic acid imparts to distilled water after neutralization with ammonia, this becoming additive in such a series. Or, again, there are forms of organic matter in soils which develop, in connection with disulphonic acid, a color resembling the yellow of the standard color solution; these, if present in this sand,

may also have had an additive effect. The sand, however, had been repeatedly treated with disulphonic acid for the purpose of removing this source of error as well as to get rid of all nitrates which might be present.

THE INFLUENCE OF EARTH MULCHES UPON THE MOVEMENT AND DISTRIBUTION OF WATER-SOLUBLE SALTS IN SOILS.

In our earlier investigations relating to the influence of deep and shallow cultivation upon the yields of crops, and in regard to the influence of mulches generally, conducted at the Wisconsin Agricultural Experiment Station, relations were observed which made it appear that mulches influence yields in other ways than by merely controlling the movement and amount of soil moisture.

CONDITIONS OF THE EXPERIMENT.

Using a set of 24 cylinders, represented in Fig. 1, p. 64, the effect of 3-inch earth mulches upon the movement and distribution of water-soluble salts in six soil types was studied during a period of 70 days. Four cylinders were charged, by careful and uniform tamping, with each type of soil, in the manner already described, and a composite sample of each taken to give the soluble salt condition of the soils when the observations were begun.

After all of the cylinders had been charged and put in place, 3 inches of the soil were removed from two of each set of four cylinders and so much of it returned in a loose condition as was required to fill them again level full.

The soils used were, in all cases, taken from the surface foot of the respective types and were placed in the cylinders after a thorough mixing of the bulk samples, in their normal moisture and textual field conditions. Water was then added to the reservoirs with the covers in place, until each had become capilliarily saturated, when all were exposed to surface evaporation under a canvas shade, which excluded the rain.

After a period of 70 days' duration, the soils were removed from the cylinders in sections and the water-soluble salts determined for the different levels.

The total amounts of water added to these different soils, under the two conditions, are given in the next table:

Amounts of water added by capillarity.

	Sandhill.	Selma Silt Loam.	Norfolk Sandy Soil.	Goldsboro Compact Sandy Soil.	Norfolk Fine Sandy Loam.	Pocoson.
	To the mulched cylinders.					
In c. c.	1044.5	2084.5	2036.5	1955.5	2794.5	2425.5
In inches	2.98	5.96	5.82	5.44	7.98	6.93
	To the unmulched cylinders.					
In c. c.	1869.5	3227.5	3504.5	3797.5	4974	3512.5
In inches	5.34	9.22	10.01	10.85	14.21	10.04

The water used was drawn from the hydrant of the field laboratory and its composition is given in Bulletin "B," "Amounts of Plant Food Readily Recoverable from Field Soils with Distilled Water," p. 94, No. 13 of the table.

The amounts of salts conveyed to these soils in the water added and the amounts which were present in the soil when the cylinders were filled are given in the next table:

Total water-soluble salts in upper 18 inches of soil at commencement of trials and the amounts added with the water, expressed in pounds multiplied by 1,000,000.

	NO_3.		HCO_3.		Cl.		SO_4.		HPO_4.		SiO_3.	
	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.
	Sandhill.											
Soil at start....	22.6	23.4	61.2	63.4	59.9	62.2	0.0	0.0	43.1	44.7	7.0	7.2
In water added.	.5	.9	4.3	7.6	10.7	19.0	9.7	17.2	3.1	5.5	22.7	40.1
	Selma Silt Loam.											
Soil at start....	385.3	416.5	306.5	331.3	326.5	352.9	1056.9	1142.2	143.8	155.4	50.4	54.5
In water added.	1.1	1.6	9.3	13.7	23.4	34.3	21.2	31.0	6.8	10.0	49.9	72.5
	Norfolk Sandy Soil.											
Soil at start....	1372.5	1442.2	166.4	174.9	399.8	420.1	1131.9	1189.4	138.9	146.0	74.2	78.0
In water added.	1.0	1.6	8.5	13.8	21.4	34.7	19.3	31.4	6.2	10.1	45.1	73.2
	Goldsboro Compact Sandy Loam.											
Soil at start....	248.2	263.3	65.0	69.0	379.7	402.7	1072.0	1137.0	159.9	169.5	21.0	22.3
In water added.	1.0	1.9	8.0	15.8	20.1	39.6	18.2	35.9	5.9	11.5	42.5	83.7
	Norfolk Fine Sandy Loam.											
Soil at start....	1821.3	1944.4	78.5	83.8	1262.1	1347.4	618.1	659.9	174.3	186.1	14.2	15.1
In water added.	1.4	2.4	11.7	20.2	29.3	50.6	26.5	45.8	8.5	14.8	61.9	106.9
	Pocoson.											
Soil at start...	695.0	713.3	236.7	242.9	153.8	157.9	50.7	42.6	149.6	153.5	42.4	43.6
In water added.	1.2	1.7	9.9	14.7	24.8	36.9	22.5	33.4	7.2	10.7	52.4	77.9

DISTRIBUTION OF SALTS IN MULCHED AND UNMULCHED SOILS AFTER A CAPILLARY MOVEMENT OF 70 DAYS.

In removing the soil from these cylinders at the close of the trials the upper 3 inches were taken out in 1-inch layers, but the balance, down to and including 18 inches, in 3-inch layers. The lower 6 inches of soil in the cylinders were not examined.

In the table which follows are given the amounts of the different water-soluble salts recovered from the cylinders carrying the different soil types under the mulched and unmulched conditions. These observations were made during the season of 1902, before the methods for the determination of bases had been devised, and hence only the movement of the negative radicles was observed:

Amounts and distribution of water-soluble salts in 6 soil types after 70 days of capillary movement under mulched and unmulched surfaces.

Depth. Inches.	NO_3.		HCO_3.		Cl.		SO_4.		HPO_4.		SiO_3.	
	Mulched.	Unmulched.	Mulched.	Unmulched.	Mulched.	Unmulched.	Mulched.	Unmulched.	Mulched.	Unmulched.	Mulched.	Unmulched.
	In parts per million of dry soil.											
	Goldsboro Compact Sandy Loam.											
0- 1	232.8	395.0	10.94	13.55	182.80	280.49	111.0	825.0	9.35	11.40	2.07	3.67
1- 2	47.8	10.0	24.74	10.30	20.20	7.18	40.0	42.7	6.70	9.20	2.88	3.71
2- 3	47.8	8.1	11.81	11.13	17.78	4.85	50.4	41.6	6.98	9.32	2.99	2.99
3- 6	46.8	8.2	12.14	8.43	9.15	7.37	50.6	26.6	6.38	8.65	3.07	3.40
6- 9	35.8	7.0	13.76	17.60	10.94	6.60	51.3	26.6	6.42	7.86	3.09	3.43
9-12	30.6	5.7	14.48	17.38	8.41	8.48	45.6	17.1	5.66	8.09	3.51	3.49
12-15	27.2	4.8	16.37	28.00	12.97	8.52	34.1	11.6	5.82	7.40	3.21	4.37
15-18	7.0	2.8	15.50	22.66	9.02	8.76	34.7	5.3	5.20	8.43	4.58	4.47
	Norfolk Fine Sandy Loam.											
0- 1	768.0	1120.0	16.34	13.91	503.80	977.20	371.26	301.0	9.82	11.70	1.69	6.79
1- 2	51.8	15.5	19.39	13.73	16.31	6.38	63.20	24.9	7.47	9.97	3.59	4.46
2- 3	38.6	12.5	15.30	15.30	8.08	8.08	56.14	19.2	7.77	8.54	3.72	3.72
3- 6	25.0	12.3	17.90	14.10	9.15	7.37	45.00	18.9	7.98	7.86	4.02	4.17
6- 9	25.3	11.0	18.10	15.20	13.46	5.89	34.20	12.5	8.09	8.09	3.89	5.45
9-12	16.1	9.9	13.95	16.88	9.38	17.17	32.40	10.4	8.20	8.20	4.37	5.56
12-15	16.2	7.9	26.80	28.88	9.78	6.13	15.45	7.1	8.54	7.60	4.52	5.72
15-18	7.8	5.7	31.50	30.18	11.89	5.41	4.33	4.9	8.79	7.80	5.06	5.87
	Pocoson.											
0- 1	1004.0	845.0	10.57	12.36	244.08	261.62	125.00	243.00	16.2	16.1	4.5	7.1
1- 2	93.6	31.2	12.14	21.40	56.30	6.66	24.74	13.49	13.6	17.6	6.9	7.7
2- 3	88.8	31.7	10.86	17.38	48.80	5.89	18.24	12.54	11.3	17.8	7.0	7.0
3- 6	91.2	33.2	10.42	16.15	24.15	10.30	18.74	11.65	10.8	18.0	10.5	7.2
6- 9	78.1	26.4	11.48	28.79	17.73	9.64	15.66	11.88	12.8	21.1	12.3	11.8
9-12	52.0	27.2	9.31	25.50	16.23	10.82	13.44	11.00	15.6	24.3	14.2	12.1
12-15	26.5	19.6	25.38	23.60	11.05	10.98	13.64	11.16	22.0	21.1	16.2	11.0
15-18	13.7	10.7	24.30	24.30	9.42	14.12	11.49	8.93	21.7	19.9	14.4	11.3
	Sandhill.											
0- 1	2.58	20.40	10.36	10.15	9.91	16.19	4.32	7.99	6.81	7.80	.66	1.36
1- 2	3.58	3.85	9.80	12.87	9.97	9.72	4.83	5.07	6.12	7.19	.66	1.04
2- 3	2.11	4.41	8.16	8.37	8.75	11.96	3.96	4.05	7.02	7.91	.68	.69
3- 6	4.00	4.61	6.56	11.74	12.19	10.60	4.11	4.11	5.13	7.28	.71	.71
6- 9	6.24	4.54	8.02	9.25	12.43	13.81	3.16	4.16	5.98	7.37	.72	.72
9-12	3.76	4.74	8.35	8.13	11.22	12.60	2.19	3.20	6.21	6.06	.75	.73
12-15	3.91	2.59	10.71	9.06	11.55	14.02	2.41	2.38	7.70	6.74	1.67	.81
15-18	1.92	2.29	12.42	9.95	12.48	10.70	1.83	1.81	7.80	7.72	1.66	1.24
	Selma Silt Loam.											
0- 1	1140.0	1076.3	7.82	10.43	317.56	74.00	554.0	1100.0	16.7	17.9	1.8	6.0
1- 2	138.0	29.2	17.40	26.42	27.86	9.15	110.0	50.6	14.8	13.6	4.1	7.3
2- 3	97.2	28.5	12.31	11.58	18.50	10.09	82.0	39.9	11.3	11.3	5.9	8.2
3- 6	98.0	26.8	9.81	14.68	14.02	13.64	85.6	34.7	11.8	12.3	6.9	6.8
6- 9	52.4	28.1	21.42	32.21	14.22	9.64	82.0	26.7	12.0	12.6	9.1	9.4
9-12	52.9	24.6	21.02	29.20	15.32	12.44	59.8	21.7	13.0	15.4	10.1	9.1
12-15	32.5	20.1	36.48	54.01	21.19	9.15	33.5	19.7	17.6	16.6	10.2	10.9
15-18	20.4	15.2	39.40	47.18	12.33	9.28	25.1	13.8	19.0	17.8	12.7	9.5
	Norfolk Sandy Soil.											
0- 1	652.0	694.0	20.49	7.26	169.47	160.33	488.0	520.0	10.36	14.0	1.00	1.07
1- 2	131.0	11.2	12.39	15.38	13.64	6.21	131.6	17.8	9.47	12.0	2.10	2.15
2- 3	50.8	9.4	14.04	14.23	7.77	7.87	45.2	17.1	8.93	11.4	2.51	2.45
3- 6	52.8	9.1	9.74	4.09	9.70	9.45	47.0	13.9	9.28	10.6	2.61	2.20
6- 9	46.8	11.5	16.78	26.12	6.46	7.98	42.7	11.9	10.93	10.7	3.01	4.81
9-12	13.9	9.3	17.60	25.27	9.83	6.55	33.3	11.0	11.85	12.6	3.05	4.91
12-15	16.9	7.3	26.82	40.48	9.25	9.15	17.1	4.5	12.13	13.6	3.11	3.82
15-18	3.1	7.8	46.04	52.97	10.52	12.97	3.6	2.4	13.52	12.5	3.69	4.01

It will be seen from this table that there came to be, at the end of 70 days, a marked inequality in the distribution of the water-soluble salts which could be recovered by washing in distilled water. Instead of the perfect uniformity which existed at the time the cylinders were charged with the soil, the 70 days of capillary movement has resulted in very large concentrations, especially of the nitrates, chlorides and sulphates, at and near the surface. The nitrates, for example, range from 20.4 parts per million at 15 to 18 inches below the surface to 1140 parts per million in the surface inch of the mulched surface; and from 15.2 parts at the bottom to 1076.3 parts at the top, where the soil was firm.

It will be seen that the water-soluble salts in the upper layer of the loose soil of the mulcheed cylinders are often greater than in the corresponding layer of the unmulched or firm surface. This difference results partly from the fact that the weight of soil in the loose condition is less than where the soil was firm, and hence the same amount of salts brought into the surface inch represents a larger number of parts per million of the soil. Because the data of the last table, p. 101, are not fully comparable, on account of the differences stated, there have been brought together in the next table the absolute amounts of the several water-soluble salts which were recovered from the respective levels. These amounts are obtained by multiplying the observed dry weights of soil recovered from each layer by the parts per million taken from the last table. As the weight of the soil was obtained in pounds the results are in pounds, but on account of multiplying by parts per million they are one million times too large, and are stated in this way to avoid long decimals. In studying the data of this table it will be needful to bear in mind that because there are approximately 3 times the amount of soil in the 3-inch layers that there are in the 1-inch layers, the amounts in the 3-inch layers appear to be relatively higher than is the case. To avoid this confusion the totals for the three 1-inch layers are also given in the table. The data of lines 0–3, 3–6, etc., to 15–18, show the distribution of the several salts in the respective levels in a strictly comparable man-

ner, and they express the true relation between the quantities of water-soluble salts which were recovered after 70 days of capillary sweeping.

Absolute amounts of water-soluble salts recovered from mulched and unmulched soils.

Depth. Inches.	NO_3.		HCO_3.		Cl.		SO_4.		HPO_4.		SiO_3.	
	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.
	In pounds multiplied by 1,000,000.											
	Sandhill.											
0- 1.......	2.1	22.3	8.3	11.1	7.9	17.7	3.5	8.8	5.5	8.5	.5	1.5
1- 2.......	3.6	4.1	9.8	13.7	10.0	10.4	4.8	5.4	6.1	7.7	.7	1.1
2- 3.......	1.8	5.0	7.1	9.5	7.6	13.6	3.5	4.6	6.1	9.0	.6	.8
0- 3.......	7.5	31.5	25.2	34.3	25.5	41.7	11.8	18.8	17.7	25.2	1.8	3.4
3- 6.......	14.4	16.7	23.7	42.6	44.0	38.5	14.8	14.9	18.5	26.4	2.6	2.6
6- 9.......	21.2	16.4	27.4	33.5	42.5	50.0	10.8	15.1	20.5	26.7	2.5	2.6
9-12.......	13.2	16.8	29.3	28.9	39.4	44.7	7.7	11.4	21.8	21.5	2.6	2.6
12-15.......	14.7	9.4	40.3	32.9	43.4	50.9	9.1	8.6	29.0	24.5	6.3	2.9
15-18.......	6.8	8.2	44.1	35.4	44.3	38.1	6.5	6.4	27.7	27.5	5.9	4.4
Sum...	77.8	98.9	190.0	207.6	239.1	263.9	60.7	75.2	135.2	151.8	21.7	18.5
	Selma Silt Loam.											
0- 1.......	826.5	1270.0	5.7	12.3	230.2	87.3	401.7	1298.0	12.1	21.1	1.3	7.1
1- 2.......	89.7	31.5	11.3	28.5	31.1	9.9	71.5	54.7	9.6	14.7	2.7	7.9
2- 3.......	76.8	29.9	9.7	12.2	14.6	10.6	64.8	41.9	8.9	11.9	4.6	8.6
0- 3.......	993.0	1331.4	26.7	53.0	275.9	107.8	538.0	1394.6	30.6	47.7	8.6	23.6
3- 6.......	277.3	85.0	27.8	46.5	39.7	43.2	242.3	110.0	33.4	39.0	19.5	21.4
6- 9.......	168.2	88.0	68.8	100.8	45.7	30.2	263.2	83.7	38.5	39.4	29.1	29.4
9-12.......	161.4	73.1	64.1	86.7	46.7	37.0	182.4	64.4	39.7	45.7	30.7	27.1
12-15.......	100.4	60.7	112.7	163.1	65.5	27.6	103.5	59.6	54.4	50.1	31.6	33.0
15-18.......	64.5	50.6	124.9	157.1	39.1	30.9	79.6	46.1	60.2	59.3	40.4	31.5
Sum...	1764.8	1688.8	425.0	607.2	512.6	276.7	1409.0	1758.4	256.8	281.2	159.9	166.0
	Norfolk Sandy Soil.											
0- 1.......	599.8	957.7	18.9	10.0	155.9	221.3	449.0	717.6	9.5	19.3	4.6	.9
1- 2.......	110.0	14.3	10.4	19.7	11.5	8.0	110.5	22.8	8.0	15.4	3.8	1.8
2- 3.......	50.8	11.5	14.0	17.4	7.8	9.6	45.2	20.9	8.9	13.9	4.3	2.5
0- 3.......	760.6	983.5	43.3	47.1	175.1	238.9	604.7	761.3	26.4	48.6	12.7	5.2
3- 6.......	194.3	31.8	35.8	14.2	35.7	32.9	173.0	48.4	34.2	36.9	16.5	9.6
6- 9.......	168.5	43.1	60.4	98.0	26.4	29.9	153.7	44.6	39.4	40.1	18.9	10.8
9-12.......	50.6	33.9	64.1	92.5	35.8	24.0	121.2	40.4	43.1	46.1	20.8	11.1
12-15.......	60.0	26.0	95.2	144.5	32.8	32.7	60.7	16.0	43.1	48.6	20.8	11.0
15-18.......	10.6	26.5	158.4	179.0	36.2	43.8	12.3	8.0	46.5	42.3	22.4	12.7
Sum...	1244.6	1144.8	457.2	575.3	342.0	402.2	1125.6	918.7	232.7	262.6	112.1	60.4

Absolute amounts of water-soluble salts recovered from mulched and unmulched soils—Continued.

Depth. Inches.	NO_3. Mulched.	NO_3. Un-mulched.	HCO_3. Mulched.	HCO_3. Un-mulched.	Cl. Mulched.	Cl. Un-mulched.	SO_4. Mulched.	SO_4. Un-mulched.	HPO_4. Mulched.	HPO_4. Un-mulched.	SiO_3. Mulched.	SiO_3. Un-mulched.
	In pounds multiplied by 1,000,000.											
	Goldsboro Compact Sandy Loam.											
0- 1......	253.8	604.4	11.9	20.7	199.3	429.2	121.0	1262.3	10.2	17.4	2.3	5.6
1- 2......	44.5	13.0	23.0	13.4	18.8	9.3	37.2	55.5	6.2	12.0	2.7	4.8
2- 3......	51.2	9.8	12.6	13.5	19.0	5.9	53.9	50.3	7.5	11.3	3.2	3.6
0- 3......	349.4	627.2	47.6	47.6	237.1	444.4	212.1	1368.1	23.9	40.7	8.1	14.1
3- 6......	185.3	31.3	48.1	32.1	36.2	28.1	200.4	101.4	25.3	33.0	12.2	13.0
6- 9......	138.6	26.6	53.3	66.9	42.3	25.1	198.5	101.1	24.9	29.9	12.0	13.0
9-12......	117.8	22.5	55.8	69.0	32.4	33.7	175.6	67.9	21.8	32.1	13.5	13.9
12-15......	102.3	19.8	61.6	116.2	48.8	35.4	128.3	47.9	21.9	30.7	12.1	18.1
15-18......	29.1	11.3	64.3	92.7	37.4	35.8	144.0	21.8	21.6	34.5	19.0	18.3
Sum...	922.4	738.7	330.5	424.5	434.2	602.4	1058.9	1708.2	139.3	200.8	76.9	90.3
	Norfolk Fine Sandy Loam.											
0- 1......	668.2	1624.0	14.2	20.2	438.3	141.7	323.0	436.5	8.5	17.0	1.5	9.9
1- 2......	36.8	18.0	14.0	15.9	11.6	7.4	44.9	28.9	5.3	11.6	2.6	5.2
2- 3......	36.7	14.4	14.5	17.6	7.7	9.3	53.3	22.1	7.4	9.8	3.5	4.3
0- 3......	741.6	1656.4	42.5	53.7	457.6	158.4	421.2	487.4	21.2	38.4	7.6	19.3
3- 6......	86.0	41.9	61.6	48.1	31.5	25.1	154.8	64.3	27.5	26.8	13.8	14.2
6- 9......	89.8	39.2	64.3	54.1	47.8	21.0	121.4	44.6	28.7	28.8	13.8	19.4
9-12......	56.5	35.3	49.0	59.9	32.9	61.0	113.7	36.9	28.8	29.1	15.3	19.7
12 15......	56.4	27.5	93.3	100.2	34.0	21.3	50.3	24.7	29.7	26.4	15.7	19.9
15-18......	27.1	20.2	109.0	107.7	41.1	19.3	15.0	17.5	30.4	27.9	17.5	21.0
Sum...	1057.4	1820.5	419.6	423.8	644.9	306.0	876.4	675.5	166.3	177.3	83.8	113.5
	Pocoson.											
0- 1......	652.6	963.3	6.9	14.1	158.7	298.3	81.3	277.0	10.5	18.4	2.9	8.1
1- 2......	75.8	30.3	9.8	20.8	45.6	6.5	20.0	13.1	11.0	17.1	5.6	7.4
2- 3......	79.0	30.4	9.7	16.7	43.4	5.7	16.2	12.0	10.1	17.1	6.3	6.7
0- 3......	807.5	1024.0	26.4	51.5	247.7	310.4	117.5	302.2	31.6	52.5	14.8	22.2
3- 6......	279.1	100.3	31.9	48.8	73.9	31.1	57.3	35.2	33.1	54.4	32.0	21.6
6- 9......	249.9	82.1	36.7	89.5	56.7	30.0	50.1	37.0	41.0	65.6	39.4	36.7
9-12......	164.3	88.1	29.4	82.6	51.3	35.1	42.5	35.6	49.3	78.6	44.8	39.1
12-15......	85.1	61.7	81.5	74.3	35.5	34.6	43.8	35.2	70.0	66.5	52.0	34.7
15-18......	45.4	34.0	80.4	77.3	31.2	44.9	38.0	28.4	71.8	63.3	47.8	35.9
Sum...	1631.2	1390.3	286.3	424.1	496.3	486.0	349.3	473.5	297.4	380.9	230.8	190.2

INFLUENCE OF CAPILLARY MOVEMENT IN SOILS UNDER NAKED FALLOW TREATMENT UPON THE AMOUNTS OF WATER-SOLUBLE SALTS IN SOILS.

One of the purposes of this investigation was to ascertain if the amount of water-soluble salts of soils change under naked fallow treatment, and if so, in what manner; and the data of the tables on pp. 100, 103 and 104, may be used to show if a measurable change has occurred during the 70 days of treatment to which the six soils have been subjected. The addition of river water to maintain capillary movement did not do violence to normal field conditions, for it was itself a ground water closely similar to that normal to the several soil types under observation. The abnormal conditions are the large and rapid movement of the water; its somewhat higher temperature; and perhaps a slightly different aeration than would be normal to fields.

If the total water-soluble salts observed in these soils at the time they were placed under treatment are increased by the amounts of salts carried to them in the water, the results may be compared with the amounts found at the close of the capillary period to show whether measurable changes have occurred. Such a comparison is made in the following table:

Changes in the amounts of water-soluble salts in the surface 18 inches of soil in cylinders, associated with naked fallow and capillary movement.

	NO_3.		HCO_3.		Cl.		SO_4.		HPO_4.		SiO_3.	
	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.
	In pounds multiplied by 1,000,000.											
	Sandhill.											
Close......	77.8	98.9	190.0	207.6	239.1	263.9	60.7	75.2	135.2	151.8	21.7	18.5
Start......	23.1	24.3	65.5	71.0	70.6	81.2	9.7	17.2	46.2	50.2	29.7	47.3
Change .	54.7	74.6	124.5	136.6	168.5	182.7	51.0	58.0	89.0	101.6	−8.0	−28.8
	Salem Silt Loam.											
Close......	1764.8	1688.9	425.0	607.2	512.7	276.7	1408.9	1758.4	256.9	281.2	159.9	166.0
Start......	386.4	418.1	315.8	345.0	349.9	387.2	1078.1	1173.2	150.6	165.4	100.3	127.0
Change..	1378.4	1270.8	109.2	262.2	162.8	-110.5	330.8	585.2	106.3	115.8	59.6	39.0
	Norfolk Sandy Soil.											
Close......	1244.7	1143.8	457.2	575.3	342.0	402.1	1125.6	918.6	232.7	262.6	112.1	60.4
Start... ..	1373.5	1443.8	174.9	188.7	421.2	454.8	1151.2	1220.8	145.1	156.1	119.3	151.2
Change..	-128.8	-299.0	282.3	386.6	−79.2	−52.7	−25.6	-302.2	87.6	106.5	−7.2	−90.8
	Goldsboro Compact Sandy Loam.											
Close......	922.5	738.6	340.7	424.5	429.2	602.5	1058.9	1708.2	139.4	200.9	76.9	90.4
Start......	249.2	265.2	73.0	84.8	399.8	442.3	1090.2	1172.9	165.8	181.0	63.5	106.0
Change..	673.3	473.4	267.7	339.7	29.4	160.2	−31.3	535.3	−26.4	19.9	13.4	−15.6
	Norfolk Fine Sandy Loam.											
Close......	1057.4	1820.5	419.7	423.7	644.9	306.1	876.4	675.4	166.3	177.4	83.8	113.5
Start......	1822.7	1946.8	90.2	104.0	1291.4	1398.0	644.6	705.7	182.8	200.9	76.1	122.0
Change..	-765.3	-126.3	329.5	319.7	-646.5	−1091.9	231.8	−30.3	−16.5	−23.5	7.7	−8.5
	Pocoson.											
Close......	1091.3	1390.2	286.3	424.0	422.4	486.1	349.2	473.6	297.4	380.9	230.8	180.2
Start......	696.2	715.0	246.6	275.6	178.6	194.8	73.2	76.0	156.8	164.2	94.8	121.5
Change..	395.1	675.2	39.7	148.4	243.8	291.3	276.0	397.6	140.6	216.7	136.0	58.7

From this table it will be seen that, in the majority of cases, there has been an increase in the water-soluble salts during the 70 days of capillary movement. In the Sandhill type, except in the case of silica, there has been an increase of 1 to 2-fold. In the Selma Silt Loam there was a loss of chlorine in one case,

but otherwise there was a large percentage of gain, the phosphates increasing 60 to 70 per cent. In the Norfolk Sand and in the Norfolk Fine Sandy Loam there were considerable losses in many cases. It is true of these soils that they are the ones which had been most heavily fertilized the season the trials were made, and an absorption was, perhaps, to be expected. There is no case where the HCO_3 has not increased and only three cases of a reduction of the phosphates.

The mean changes for the six soil types are given in the next table:

Mean change in water-soluble salts in six soil types after 70 days of naked fallow and capillary movement.

	NO_3.	HCO_3.	Cl.	SO_4.	HPO_4.	SiO_2.
	In pounds multiplied by 1,000,000.					
Close	1086.7	489.4	410.6	874.1	223.6	109.5
Start	780.4	168.1	472.5	701.1	147.1	96.5
Change	306.3	321.3	−61.9	173.0	76.5	13.0
Per cent., change	39.2	191.1	13.1	24.6	52.0	13.5

These general averages point with some assurance to a tendency of naked fallows to increase the water-soluble salt content of the soil, especially if it was low to begin with, and the observed relations are in accord with the usual immediate increased productive power of naked-fallow fields, if it is true that an increase in the amounts of readily water-soluble salts in soils favor an increase of yield.

INFLUENCE OF 3-INCH EARTH MULCHES ON THE DISTRIBUTION OF NITRATES, SULPHATES AND CHLORIDES, IN SOILS.

If the mean amounts of nitrates, sulphates and chlorides, which were recovered from the respective levels in the six soil types under the loose and firm surfaces are brought together, they stand as given in the next table:

Mean distribution of nitrates, sulphates and chlorides, in six soil types under mulched and unmulched surfaces.

Depth. Inches.	NO_3. Mulched.	NO_3. Un-mulched.	Cl. Mulched.	Cl. Un-mulched.	SO_4. Mulched	SO_4. Un-mulched.
	In pounds multiplied by 1,000,000.					
0- 1	500.5	907.0	198.4	199.3	229.9	666.7
1- 2	60.1	18.5	21.4	8.6	48.2	30.1
2- 3	49.4	16.8	16.7	9.1	39.5	25.3
0- 3	610.0	942.4	236.5	216.9	317.5	722.1
3- 6	172.7	51.2	43.5	33.2	140.4	62.4
6- 9	139.4	49.2	43.6	31.0	133.0	54.4
9-12	94.0	45.0	39.8	39.3	107.2	42.8
12-15	69.8	34.2	43.3	33.8	66.0	32.0
15-18	30.6	25.1	38.2	35.5	49.2	21.4
Total	1116.5	1147.1	444.9	389.7	813.3	935.1
Percentage	100.00	102.74	100.00	85.59	100.00	115.08

From this table it is seen that the more rapid capillary movement upward under the unmulched surfaces had so counteracted diffusion downward as to leave all of these salts much more concentrated under the unmulched surfaces. Comparing the data in the table it will be seen that the 3 to 6 inch level contains more than 3 times as much nitrates and more than twice as much sulphates under the mulched surfaces, and similar relations hold down to and including the 12- to 15-inch level.

In the case of chlorine, whose rate of diffusion is higher, there is less difference, but the tendency here is clearly marked.

It has been shown in preceding pages that the three important bases are rapidly carried upward also by capillarity, and it is to be expected that had these been determined in this series, somewhat similar relations would have been found.

INFLUENCE OF 3-INCH EARTH MULCHES ON THE DISTRIBUTION OF PHOSPHATES, SILICA AND BICARBONATES.

In the next table there are brought together the mean values showing the relative distribution of phosphates, silica and bicarbonates under the two conditions of surface.

Mean distribution of phosphates, silica and bicarbonates in six soil types under mulched and unmulched surfaces.

Depth. Inches.	HCO_3.		HPO_4.		SiO_2.	
	Mulched.	Un-mulched.	Mulched.	Un-mulched.	Mulched.	Un-mulched.
	In pounds multiplied by 1,000,000.					
0- 1	11.0	14.7	9.4	17.0	2.2	5.5
1- 2	13.1	18.7	7.7	13.1	3.0	4.7
2- 3	11.3	14.5	8.2	12.2	3.8	4.4
0- 3	35.3	47.7	25.3	42.2	8.9	14.6
3- 6	38.2	38.7	28.7	36.1	16.1	13.7
6- 9	51.8	73.8	32.2	38.4	19.3	18.7
9-12	48.6	69.9	34.1	42.2	21.3	18.9
12-15	80.8	105.4	41.5	41.1	23.1	19.9
15-18	96.9	108.2	43.0	42.5	25.5	20.5
Total	351.6	443.7	204.8	242.5	114.2	106.3
Percentage	100.00	126.19	100.0	118.63	100.00	93.08

In the case of the phosphates, silica and bicarbonates, the distribution, shown by the data of the table, is, in some respects, the reverse of what occurred with the nitrates, chlorides and sulphates; with these, the amounts decrease with great rapidity through the first three inches and continue to decrease, only less rapidly to the bottom; with the phosphates and the other two radicles, there is but a small decrease, if any, through the first three inches, but a well marked tendency for the amounts to increase with the depth. This general difference, in the behavior of the two groups of salts, is clearly shown in the diagram, Fig. 7, p. 110, where the mean combined amounts of NO_3, SO_4 and Cl, have been plotted as a single curve, on one-third the scale used for plotting the other three ingredients. From this figure it will be seen how strong is the tendency for the members of the nitrate group to concentrate at the surface, while the others, and in a less marked degree, show the reverse order of distribution.

It should be observed, that in each case, more salts were recovered at the top from the soil which had sustained the greatest evaporation. Moreover, there were more phosphates and silica in the surface inch than there were in the second and third inch, which shows that this reversal of the order in the distribution of

the two groups of salts is not due entirely to an effect the more soluble salts may have had upon the solubilities of the other three.

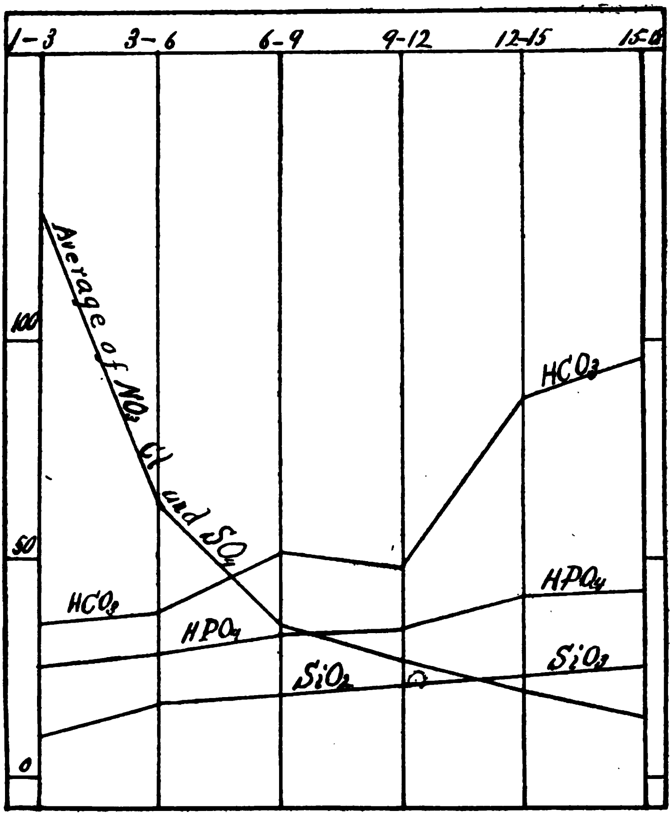

FIG. 7.—Showing the effect of capillarity on the mean distribution of water-soluble salts in 6 soil types under an earth mulch of 3 inches. The NO_3, SO_4 and Cl curve is plotted on one-third the scale of the other three.

Bearing of Capillary Movement of Salts Upon Soil Management.

CULTIVATION TO MAKE WATER-SOLUBLE PLANT FOOD MATERIALS MORE AVAILABLE.

It is evident, from the tendencies of good earth mulches to restrain the rise of water-soluble salts to the immediate surface of the field, which has been demonstrated by the series of experiments of the preceding section, that in so far as the presence of

water-soluble salts in the zone of greatest root activity may influence yield, good surface cultivation must be beneficial in holding the nitric acid, lime, magnesia and potash well down within the zone of 3 to 15 inches, where the roots of crops are usually most abundant, and for this reason, where the salts may be expected to be most immediately available.

The table on p. 108 shows that, for an average of 6 soil types, the amounts of nitric acid (NO_3) in the layer of soil 3 to 6 inches below the surface, had come to be in the ratio of 172.7 under the good 3-inch mulch, to 51.2, where no mulch was maintained; and this difference, so far as can be seen, was due wholly to the effect of the mulch. In the 6 to 9 inches the mean ratio was 139.4 to 49, or nearly three times as much nitrates had accumulated under the mulch; and even at 12 to 15 inches below the surface the ratio had come to be 69.8 to 34.2, or twice as much nitric acid existed there; and this is one of the most essential plant food materials, for it is the immediate source of all the nitrogen of cultivated crops, at least so far as is as yet demonstrated.

In Figures 8 and 9, p. 112, there are two illustrations of a form of surface cultivation very generally practiced in the South, but which, for all except very unusual soils in very wet seasons, or for certain special crops, is far from the best. In both of the fields there shown a small plow had been run close to the row, first throwing the dirt away from the plants, leaving a firm, moist furrow bottom exposed to the drying action of the hot sun and winds and, at the same time, the loose earth turned away left in a condition to dry out completely. After a day or two the dried and loose earth was again turned back against the row with the plow and another furrow bottom left exposed to the drying action which brings the nitrates, lime and other soluble salts to the immediate surface where they are useless to the crop and where the first heavy rain is liable to carry much of them away in the surface drainage. The curled condition of the leaves of the corn, as shown in the engraving, Fig. 8, is the direct effect of this faulty cultivation rather than the result of a necessary deficiency of soil moisture at the time.

FIG. 8.—Showing ridge and furrow cultivation of corn and wilting which is chiefly the result of the cultivation.

FIG. 9.—Showing recently plowed field of cabbage, leaving surface in condition for rapid evaporation.

LOSS OF PLANT FOOD IN SURFACE DRAINAGE.

When the methods of cultivation are such as to intensify the concentration of water-soluble salts at the immediate surface, and where the texture of the soil, the character of the rainfall and the topography are such as to cause frequent surface drainage, there must be, of necessity, heavy losses of soil fertility as the result of such conditions.

It was shown, from the data of the table, p. 64, that through capillary concentration during 15 to 20 days, 60 per cent. of all nitrates contained in the surface foot may be brought into the surface 2 inches, and much the larger share of this 60 per cent. is carried to or very near the immediate surface. At the end of less than 5 days the surface 2 inches of soil contained 127.93 parts per million of dry soil, while the 10 to 12 inch level contained but 2.61 parts. Rapid movements like these under consideration are liable to occur whenever very drying weather follows a rainfall which leaves the surface 12 inches of soil nearly saturated with water, and with it there must be a concentration of nitric acid and lime at the immediate surface, with other salts also.

Where the granular structure of the soil is feeble, as it is so often in the South, heavy rains, and even very moderate ones, so puddle the immediate surface that the water does not enter the soil readily but quickly flows to the lowest places, carrying with it the soluble salts which have been concentrated at the surface and, if the fields are furrowed, as is shown in the two engravings, much of the rainfall is liable to pass away in surface drainage and with it whatever of salts have been dissolved.

Deeper plowing, which incorporates more of organic matter, and flat cultivation are two essential conditions which will very materially lessen these bad effects.

BULLETIN "D."

Absorption of Water-soluble Salts by Different Soil Types.

Between the time of the earlier studies of Thompson and Way, beginning about 1845 and extending on into the later 60's, a large amount of work was done, by various observers, on the absorptive power of soils over substances carried in solution when brought in contact with them and allowed to remain there during different intervals of time under different conditions.

The work done along these lines was very carefully and thoroughly reviewed by Johnson* in 1873, who then pointed out its practical bearings in a very helpful and masterful way.

In lines of investigation of the character of those which have been presented in Bulletins B and C this matter of the absorptive power of soils could not be left out of consideration and references have been made to it in speaking of the development of the methods for determining small quantities of various salts in soil solutions.

On the Extent of the Power of Soils to Absorb Ammonia.

OBSERVATIONS OF WAY.†

After making a number of qualitative experiments Way undertakes more exact quantitative studies, and first in regard to the absorption of ammonia, in which he uses different soils and

*How Crops Feed. Edition 1902, pp. 333-361.
† Journal Royal Agricultural Society of England, Volume II, 1850, pp. 313-379.

solutions of both ammonia and ammonium chloride, each having a strength of a little above .3 per cent. of ammonia.

The following are his results put in tabular form:

Amounts of ammonia absorbed by soils.

Reference.	Kind of Soil.	Ratio of Soil to Solution.	Time of Digestion.	Absorption in Parts. Per 100.	Absorption in Parts. Per Million.
		*Ammonia solution .3173 per cent. ammonia.			
Exp. 63, p. 341.	Loamy soil....	760 to 1787	2 hours.	.3083	3083
Exp. 64, p 342.	Light soil...............	456 to 4082	2 hours.	.3921	3921
Exp. 65, p. 342.	Loam soil............ .		2 hours.	.3504	3504
Exp. 66, p. 343.	Loam soil....		2 hours.	.3438	3438
Exp. 66, p. 343.	Loam soil..............		16-18 hrs.	.2652	2652
		Ammonium chloride sol'ion .3060 pr ct. ammonia.			
Exp. 67, p. 344.	Black soil	594 to 3988	2 hours.	.3478	3478
Exp. 69, p. 346.	Pipe clay...............	400 to 4000	2 hours.	.2847	2847
Exp. 70, p. 347.	Pipe clay and chalk .	450 to 4000	2 hours.	.2820	2820
Exp. 79, p. 354.	Pipe clay digested in HCl+ chalk..........	2200 to 4000	2 hours.	.2010	2010
Exp. 80, p. 354.	Pipe clay dig'ed in HCl	2200 to 4000	2 hours.	.1248	1248
Exp. 80, p. 355.	Clay subsoil...........	2200 to 4000	24 hours.	.0818	818

It will be observed that very large amounts of ammonia are absorbed from the two kinds of solutions by the soils used. From the standpoint of field problems and conditions Way's solutions were far too strong to give the precise knowledge which is needed to satisfactorily illuminate the absorption phenomena for the very dilute solutions which nearly always occur, under field conditions, in cultivated soils.

OBSERVATIONS OF VOELCKER.*

Voelcker, following Way, did a large amount of work bearing upon the absorption and retention power of soils for not only ammonia but for other substances as well. To obtain the results here cited he used five soils:

1. A calcareous clay.

2. A fertile loam, containing a little lime, mixed in equal proportions with its clay subsoil.

*Journal Royal Agricultural Society, Volume XXI, 1860, p. 105.

3. The surface and subsoil of a heavy clay field containing little sand.

4. A sterile, sandy soil, containing much organic matter and scarcely any lime.

5. Pasture land, being a vegetable mould containing abundance of organic matter and a fair proportion of sand and clay.

The ammonia solution used by him contained .332 grains per 1000 of NH_3, or at the rate of 332 parts per million of solution. His results follow:

Amounts of ammonia absorbed by five soils.

Kind of soil.	Ratio of soil to water.	Time of digestion.	In parts per million of dry soil.	Percentage relations.
1. Calcareous soil	30 to 140	3 days.	882	100.00
2. Fertile loam and subsoil.	35 to 140	3 days.	804	91.16
3. Heavy clay soil.	35 to 140	3 days.	754	85.49
4. Sterile sandy soil	35 to 140	3 days.	868	98.41
5. Pasture land	35 to 140	3 days.	576	65.30

When he used a still stronger solution, on the same samples of soil, containing 673 parts of NH_3 per million of solution, he obtained the results given in the next table. The digestion was allowed to continue 3 days and 14,000 grains of the stronger solution were used in each case.

Amounts of ammonia absorbed by second treatment.

Kind of soil.	In parts per million of dry soil.	Percentage relations.
1. Calcareous soil	1519.3	98.89
2. Fertile loam and subsoil	1536.3	100.00
3. Heavy clay soil	1124.0	79.67
4. Sterile sandy soil	1522.0	99.07
5. Pasture land.	1521.7	99.05

In a third series Voelcker used 4 solutions of different strength on the same soil, which was a moderately stiff calcareous clay. In each case 7,000 grains of solution were agitated with ¼ lb. of soil, and after four days the solutions were examined.

Amounts of ammonia absorbed by the same soil from solutions of different strength.

	Strength of solution.	Ammonia absorbed by the soil.
	In parts per million.	
1	634	1320
2	304	640
3	176	260
4	88	100

Regarding these experiments Voelcker states that, while the two stronger solutions gave up to their soils about half of their ammonia, the third solution only gave up one-third, and the fourth but one-fourth. Relatively larger absorptions, therefore, took place from the stronger solutions.

THE POWER OF SOILS TO RETAIN AMMONIA.

Another series of observations was made by Voelcker to measure the power of a given soil to hold back the absorbed ammonia against washing with water.

He used a soil which had absorbed at the rate of 4.655 grains of ammonia for each 1750 grains of soil, or 2660 parts per million. This sample was washed 7 consecutive times, using each time 7,000 grains of distilled water. His results appear below:

Amounts of ammonia recovered from one-fourth lb. of soil by 7 consecutive washings with 7000 grains of water.

	Ammonia.	
	Grains.	Parts per million of soil.
First 7000 grains of water removed	.236	134.9
Second 7000 grains of water removed	.642	366.0
Third 7000 grains of water removed	.610	348.5
Fourth 7000 grains of water removed	.622	355.4
Fifth 7000 grains of water removed	.120	68.6
Sixth 7000 grains of water removed	.193	110.3
Seventh 7000 grains of water removed	.228	130.3
Total recovered	2.651	1514.0
Total absorbed	4.655	2660.0
Total retained	2.004	1146.0

Only a little more than one-half of the absorbed ammonia had thus been recovered.

In still another series of observations Voelcker used ammonium chloride, as Way had done, and upon the same series of soils which he used in the cases first cited. His solution contained 360 parts per million of NH_3, and 3500 grains of soil were used to 14000 grains of solution, the determinations being made after 3 days.

In another series, but on the same soils, he used a solution of ammonium sulphate which contained 288 parts per million of ammonia. The ratio of soil to solution was 3500 to 14000. The following are the results:

Amounts of ammonia absorbed by five soils from solutions of ammonium chloride and ammonium sulphate.

	From NH_4 Cl.	From $(NH_4)_2$ SO_4.
	NH_3.	NH_3.
1. Calcareous soil absorbed in parts per million.........	680	608
2. Fertile loam and subsoil absorbed in parts per million	760	640
3. Heavy clay soil absorbed in parts per million..... ...	800	576
4. Sterile sandy soil absorbed in parts per million..	160	256
5. Pasture land absorbed in parts per million..........	640	448

The sandy soil has, in each case, absorbed least ammonia, but otherwise the results do not show much tendency to a marked difference in absorptive effect; but the question naturally arises whether, in experiments conducted under these conditions, a nitrification of the ammonia salts may not have occurred, and more with one soil than with another.

OBSERVATIONS OF O. KULLENBERG.*

This investigator, in his absorptive studies, used a soil from the Ida-Marienhutte Experiment Station, which, when digested in water and in hot hydrochloric acid, gave the following results:

*Hoffman's Jahresbericht der Agrikultur-Chemie, 1865, p. 15.

Materials recovered from soil used in ammonia absorption experiments.

	Soluble in 2.5 times its weight of cold water.	Soluble in three times its weight of HCl, 1.17 sp. gr.	Residue insoluble in HCl.
Organic matter	.0116	2.1380	....
Lime	.0065	.2436	.3959
Magnesia	.0022	.2846	.2023
Iron oxide	.0045	1.5912	.4398
Alumina	.0022	1.8480	5.3483
Potash	.0012	.1950	2.1024
Soda	.0027	.0612	.9588
Sulphuric acid	.0035	.0413	....
Phosphoric acid	.0006	.0863	....
Chlorine	.0055	.0059	....
Silicic acid	.0122	.0930	78.5175
Insoluble	.0082	87.9650	....
Water driven off at 150° C	....	5.2840	....
Manganese oxide	....	.2412	....
Total	.0609	100.0783	87.8650

The soil also contained .0059% ammonia, .0105% nitric acid and .0673% total nitrogen. Four strengths of solution were used in the ratio of 1, 2, 4 and 10, and 100 grams of soil were digested 3 days in 250 c. c. of solution. The results appear in the next table.

Amounts of ammonia absorbed by a soil from different strengths of ammonia salts.

Solutions Used.	Ammonia, NH_3, in Solution. Before absorption.	After absorption.	Ammonia absorbed.
	In parts per million.		
Chloride of ammonia (NH_4Cl)	160	83.2	229
	340	197.6	375
	680	448.0	612
	1700	1392.4	811
	3400	2953.2	1174
Nitrate of ammonia (NH_4NO_5)	160	83.2	229
	340	199.2	371
	680	446.4	616
	1700	1370.0	871
	3400	2914.8	1280
Sulphate of ammonia (NH_4O, SO_3)	160	60.0	290
	340	184.8	409
	680	419.2	688
	1700	1255.2	1173
	3400	2869.2	1400
Carbonate of ammonia ($2NH_4O, 3CO_2$)	160	71.2	260
	340	184.4	410
	680	398.0	744
	1700	1232.8	1233
	3400	2734.8	1755
Phosphate of ammonia ($NH_4O, 2HO, PO_5$)	160	55.2	307
	340	137.2	535
	680	331.6	919
	1700	941.6	2000
	3400	2151.6	3294

These observations show a large absorption of ammonia in whatever form it enters the solution, but it must also be said that even the weakest solution, 160 parts per million, is concentrated, when compared with normal soil solutions. The strongest solutions used contained 3400 parts per million. The largest absorption shown by the table is 3294 parts per million of the soil, while the smallest is 229 parts.

Kullenberg tried recovering the ammonia again, by percolating distilled water through the soil placed in a funnel. He digested during 24 hours 100 grams of this soil with 250 c. c. of an ammonium phosphate solution, which contained .7260 grams of phosphoric acid and .2911 grams of ammonia; then added enough water to obtain a filtrate of 250 c. c., repeating the addition of water, with the results as given in the next table.

Amounts of phosphoric acid and ammonia washed away from soil with distilled water.

	Phosphoric Acid.		Ammonia.	
	Grams.	Parts per million.	Grams.	Parts per million.
1st 250 c. c.	.0927	927	.0187	187
2nd 250 c. c.	.0255	255	.0054	54
3rd 250 c. c.	.0140	140	.0045	45
4th 250 c. c.	.0095	95	.0026	26
5th 250 c. c.	.0076	76	.0009	9
Total.	.1493	1493	.0321	321

Enough has been cited to show the tendency to absorption from a solution of ammonia by soils when the solutions are strong.

Absorption of Potash by Soils.

OBSERVATIONS OF VOELCKER.*

There have been brought together here in tabular form, with additional data, the results of a considerable number of the absorption experiments of Voelcker, without commenting on his mode of procedure more than is indicated by the table, as it was

*Journal Royal Agricultural Society, Volume XXI, 1860, p. 105.

similar to that adopted by him in his work regarding the absorption of ammonia, already cited.

Amounts of potash absorbed by different soils.

Type of Soil.	Ratio of soil to water.	Time of contact with solution. Days.	Absorbed by soil. K_2O.	Retained by solution. K_2O.	K_2O given to soil by solution left, when retaining 20 per ct.	K_2O given to soil by solution left, when retaining 10 per ct.
	In parts per million.					
	First Series.					
1 Calcareous soil	1 to 8	4	6400.0	413.0	82.60	41.30
2 Stiff clay	1 to 8	4	6510.0	399.0	79.80	39.90
3 Fertile sandy loam	1 to 8	4	5690.0	501.0	100.20	50.10
4 Pasture land	1 to 8	4	6570.0	390.0	78.00	39.00
5 Marly soil	1 to 8	4	7260.0	305.5	61.10	30.50
6 Sterile sand	1 to 8	4	6160.0	443.3	88.70	44.30
	Second Series.					
1 Soil No. 7	1 to 2	1	5917.9	1221.6	204.30	122.20
2 Soil No. 12	1 to 2	1	5435.5	1575.0	315.00	157.50
	Third Series.					
1 Soil No. 7	1 to 2	1	4714.8	1684.8	337.00	168.40
2 Soil No. 12	1 to 2	1	4808.8	1619.4	323.90	161.90
3 Marly soil	1 to 8	4	3671.0	706.5	141.30	70.70
4 Sterile sandy soil	1 to 8	4	1189.0	1016.7	203.30	101.70
	Fourth Series.					
1 Calcareous soil	1 to 8	4	3578.0	744.8	149.00	74.50
2 Clay soil	1 to 8	4	3970.0	695.8	139.20	69.60
3 Fertile light sandy loam	1 to 8	4	2626.0	863.8	172.80	68.40
4 Pasture land	1 to 8	4	3758.0	722.3	144.50	72.20
5 Soil No. 7	1 to 2	1	5066.0	1641.0	328.20	164.10
6 Soil No. 12	1 to 2	1	6903.0	722.6	144.50	72.30
7 Sterile sandy soil	1 to 8	4	1465.0	944.6	198.90	99.50
8 Marly soil	1 to 8	4	3373.0	756.2	151.20	75.60
1 Clay marl	1 to 4	3	3776.0	755.0	155.00	75.50

For this absorption work Voelcker's solutions were all strong, ranging, with two exceptions, from 1213 to 6617 parts per million of K_2O. The Nos. 3 and 4 of the third series contained only 215.7 parts per million, which is still higher than occurs in natural soils, judged from amounts recovered by single washings of short duration.

In the last two columns of the table have been set the amounts of K_2O in parts per million of dry soil which 20 per cent. and 10 per cent. of soil moisture would carry if it had the residual strength of the several solutions; or the strength after they had

come in contact with the soil and had been weakened by whatever absorption took place.

The amounts of potash used in these solutions were so large that it can hardly be expected to show well any differential effect of the different soils in removing the potash from solution; moreover, the number of observations is too limited, but the results are suggestive of differential effects.

There are four soils, in the table, which were used in each of these series, and the amounts of potash absorbed in these trials are grouped in the table below:

Amounts of potash absorbed by four soils.

	No. 7.	No. 12.	Marly soil.	Sterile sand.
	In parts per million of dry soil.			
1	5917.9	5435.5	7260	6160.0
2	4714.8	4808.0	3671	1016.7
3	5066.0	6903.0	3373	1465.0
Average	5232.9	5715.8	4768	2880.6
Percentage amounts	91.55	100.00	83.42	50.39

There is thus shown a difference in the absorptive effect of these four soils ranging from 8 to 50 per cent.

OBSERVATIONS OF WAY.*

In the six trials made by Way, which are here cited, he used three strengths of solution, two prepared from potassium nitrate and the third from caustic potash. Their strengths were:

1st solution 8255 parts per million of potash.
2nd solution 10029 parts per million of potash.
3rd solution 10023 parts per million of potash.

When 2000 grains of white pottery clay were digested with 4000 grains of the first solution, for several hours at ordinary temperature, it was found that 100 grains of the clay had absorbed .4366 grains of potash, or at the rate of 4366 parts per million of the clay.

When the second solution was used, in the same ratio as in the preceding case, the absorption amounted to 4980 parts per million, after a contact with the clay during 24 hours.

*Journal Royal Agricultural Society, Volume II, 1850, p. 356.

In the next four trials the third solution was used and the amounts of potash absorbed were:

Exp. 83 Potash absorbed = 10500 parts per million of clay.
Exp. 84 Potash absorbed = 11716 parts per million of clay.
Exp. 85 Potash absorbed = 12154 parts per million of clay.
Exp. 86 Potash absorbed = 20870 parts per million of clay.

In experiment 83 the digestion covered 12 hours with the solution cold, in the ratio of 2000 of soil to 4000 of solution.

In experiment 84 the mixture was boiled one-half hour.

In experiment 85 the clay was first treated with hot hydrochloric acid and afterwards as in experiment 84.

In experiment 86 a yellow clay from Cromwell was used, first treated with hydrochloric acid, boiling one hour, and subsequently digested, at high temperature, 24 hours; then washed with distilled water and dried before using. The ratio of clay to solution was 500 to 2000 in this case.

OBSERVATIONS OF E. PETERS.*

To obtain the results here cited Dr. Peters prepared a quantity of a rather clayey soil derived from the disintegration of a claystone porphyry, the analysis of which is given in Bulletin "B," p. 7. Solutions containing different potash salts in different amounts were prepared and 100 grams of the air-dry soil were digested in 250 c. c. of these solutions during 24 hours; the soils being introduced into a stoppered flask and the mixtures, at first, subjected to vigorous shaking. Portions of the liquid above the soil were drawn off with a pipette for analysis.

There is given in the next table two sets of absorption results, one with the solution cold and in contact with the soil 24 hours, the other, where the soil was boiled in the solution one-fourth hour and then allowed to stand 24 hours.

*Die landwirthschaftlichen Versuchs-stationen, Volume 2, p. 113.

Amounts of potash absorbed from different solutions.

	Solution contained	Amounts Absorbed from solution cold K_2O.	Amounts Absorbed from solution boiled K_2O.	Percentage relation.
	In parts per million of dry soil.			
Potassium chloride	2355.5	1990	2018	34.80
Potassium chloride	4711.0	3124	3617	....
Potassium chloride	9422.0	4503	4567	....
Potassium sulphate	2355.5	2069	2368	40.48
Potassium carbonate	2355.5	3154	4018	69.30
Potassium hydrate	2355.5	4018	4438	76.54
Potassium phosphate	2355.5	4895	5798	100.00

These results appear to establish, clearly, that all salts of potash are not absorbed in like amounts from solutions containing the same amounts of K_2O, the smallest absorption occurring with the chloride and the largest with the phosphates.

Heating to boiling for one-fourth hour has increased the absorption very materially while we have found that heating soils to dryness increases the amounts of most salts which may be recovered from them with distilled water, as pointed out in Bulletin B, p. 64.

In another series of experiments where Dr. Peters varied the time of digestion from 1/4 hour to 14 days, using the same KCl solution, there was no certain increase beyond 8 hours, and the difference between 1/4 hour and 14 days is only

$$2037 - 1417 = 620.$$

Peters made another series of observations in which he treated four different soils with the same solution of potassium chloride containing 2355.5 parts per million of K_2O, using 250 c. c. of the solution to 100 of soil. These were the mean results of his determinations:

Amounts of potash absorbed by four soils from a solution of KCl.

Name of Soil.	Texture. Coarse sand. Per cent.	Texture. Fine sand. Per cent.	Texture. Fine clay. Per cent.	K_2O in parts per million of dry soil.	Percentage differences.
Calcareous soil	25.50	33.10	41.40	3238	100.00
Colditz loam soil	39.68	28.04	32.28	1928	59.54
Folgengutes soil	23.14	43.70	33.16	1841	56.86
Calcareous sandy soil	51.62	33.15	15.23	1495	46.17

RECOVERY OF ABSORBED POTASH.

Dr. Peters made a series of observations to measure the amounts of absorbed potash he could recover again from the soil after absorption had taken place, using distilled water. Working with some of the same soil, he digested 100 grams 24 hours with 250 c. c. of a potassium chloride solution containing 2.3555 grams per liter of K_2O. At the end of this time he drew off 125 c. c. of the solution, replacing as much more distilled water, repeating the operation at the end of succeeding 24 hours, until he had obtained the 10th extraction. From his analyses and computations he determines that the following amounts of potash, which had been observed, were redissolved by the action of the cold water.

Amounts of absorbed potash redissolved by water in successive treatments

2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	9th.	10th.	Total.
In parts per million of dry soil.									
First series.									
48.0	75.0	70.0	76.0	78.0	105.0	83.0	87.0	102.	704.0
Second series.									
75.0	96.0	82.0	69.0	75.0	82.0	112.0	201.0	83.0	875.0

In the first series the original absorbed amount of K_2O was 1937 and in the second 2114 parts per million of the soil; there were, therefore, still left in the soil

First series 1937−704.0=1233 parts per million of K_2O.
Second series 2114−875.0=1239 parts per million of K_2O.

The strengths of the solutions used in these various experiments are so great that it is, perhaps, impossible to foresee what would result with solutions whose strength is more nearly what occurs in average field soils.

Starting again with 1000 grams of soil placed in a large flask, he added 1000 c. c. of a potassium chloride solution containing 28.8066 grams of K_2O. The soil absorbed, according

to analysis, 2.7504 grams, equal to 2750.4 parts per million of the K_2O, this having occurred at the end of two days. At this time 250 c. c. of solution were removed and 2250 c. c. of water put in its place, when it was vigorously shaken and allowed to stand two more days. At the end of this time 1500 c. c. of solution were removed and as much more water added, the operation being repeated 8 times, making determinations on each portion of solution removed.

The results stand as given in the next table:

Amounts of potash redissolved after absorption by a soil.

No. of Extract.	Retained in former Solution in soil.				Amounts found.				Amounts.	
									Absorbed.	Redissolved.
	CaO.	MgO.	K_2O.	Na_2O.	CaO.	MgO.	K_2O.	Na_2O.	K_2O.	K_2O.
	In parts per million.									
2......	109.0	11.2	19542.2	18.1	110.9	9.3	19704.4	19.3	2588.2	162.2
3......	55.5	4.7	9852.2	9.7	53.9	4.3	9932.1	9.3	2508.3	79.9
4......	27.0	2.2	4966.1	4.7	26.9	....	5041.7	4.2	2432.7	75.6
5......	13.5	....	2520.9	2.1	13.4	....	2590.1	2.1	2363.5	69.2
6......	6.7	....	1295.1	....	10.1	....	1364.5	....	2294.1	69.4
7.....	5.1	....	682.3	....	....	....	769.5	....	2206.9	87.2
8......	....	....	384.8	....	....	....	459.6	....	2132.1	74.8
9......	....	....	229.8	....	....	....	294.9	....	2067.0	65.1
10......	....	....	147.5	....	....	....	202.4	....	2012.1	54.9
Total	216.8	18.1	39620.9	34.6	215.2	13.6	40359.2	34.9	20602.9	738.3

It is seen from the last column of this table that, from the standpoint of the amounts of potash usually found in soil moisture, a large amount was still recovered by the 10th digestion, equal to nearly 55 parts per million of dry soil, which is more than double that usually recovereed by single short period washings. Moreover, after the second, until the 10th, the amounts of potash redissolved each time by the water were about the same, or about 77 parts per million of soil as an average.

In addition to the experiments cited, relative to the recovery of potash from soils, after absorption, Peters compared the effects of carbonic acid and weak solutions of acetic and hydrochloric acid. The results of these observations are brought together in the next table.

Amounts of potash absorbed by soils recovered with dilute acid solutions.

Soil used.	CaO.	MgO.	K_2O.	Na_2O.	SO_3.	P_2O_5.
	In parts per million of dry soil.					
	Dissolved with water holding carbonic acid.					
Ordinary untreated soil	1490	60	84	46	....	....
Ordinary untreated soil	1490	60	92	18	....	....
Soil with 1535 p.p.m. absorbed	828	24	378	32	....	....
Soil with 1535 p.p.m absorbed	828	36	554	8	....	....
Soil with 1226 p.p.m. absorbed	918	80	488	20	....	....
Soil with 1226 p.p m. absorbed	904	64	548	20	....	....
	Dissolved with dilute acetic acid.					
Ordinary untreated soil	3290	72	355	260	....	....
Ordinary untreated soil	3290	60	355	280	....	....
Soil with 1535 p.p.m. absorbed	3010(?)	75	915	160	....	....
Soil with 1535 p p.m. absorbed	2625	64	1085	180	....	....
Soil with 1226 p.p m. absorbed	2860	32	1010	115	....	....
Soil with 1226 p.p m absorbed	2842	32	1010	190	....	....
Soil with 2039.6 p p.m. absorbed	2212	60	1291	83	....	....
	Dissolved with dilute hydrochloric acid.					
Ordinary untreated soil	3584	128	636	520	240	1024
Ordinary untreated soil	3472	180	636	500	240	1024
Soil with 1535 p.p.m. absorbed	2676	106	2216	328	172	832
Soil with 1535 p.p m. absorbed	2620	110	2060	404	240	832
Soil with 1226 p p.m. absorbed	2820	80	1852	348	172	1088
Soil with 1226 p.p.m. absorbed	2820	96	1960	336	172	1028
Soil with 2039.6 p.p.m. absorbed	2072	96	2628	244	....	....

To obtain the results with carbonic acid, soil was used which had previously been treated with a potassium chloride solution and had then been washed with water equal to 4.5 to 5 times the volume of the chloride solution. After this treatment the two samples, under experiment, still retained 1535 and 1226 parts per million of absorbed K_2O. The soils were then digested with 5 times their weights of distilled water, previously saturated with carbonic acid, in closed flasks during 8 days, the water being recharged with carbonic acid 4 times in that interval.

It would have been extremely helpful, in considering these results, if there had been introduced into the series samples which were simultaneously treated with distilled water alone. In his preliminary treatment of a sample of the same soil he did recover with water 24 parts per million of K_2O from the air-dry soil, equal to 25.77 parts of the water-free soil.

In the cases treated with dilute acetic acid the soil was di-

gested in 8 times its weight of a solution containing 1 part of acid to 2 parts of water; those treated with dilute hydrochloric acid were digested hot in a solution having the ratio of 1 of acid to 3 of water.

It will be seen from the table, p. 127, that the hot hydrochloric acid digestion extracted from the ordinary soil, 636 parts per million of K_2O; from that which had absorbed 1535 parts of K_2O there were recovered an average of 2138 parts; and from that which had absorbed 1226 parts there were recovered 1906 parts, 2628 parts being dissolved from the one which had absorbed 2039.6 parts per million of its weight. Adding to the amounts, which the soils had absorbed, the 636 parts recovered from the untreated soil, and then comparing these sums with the amounts recovered from the soils which had absorbed known amounts of potash, the results appear as below:

	In parts per million of soil.		
K_2O in untreated soil	636	636	636
K_2O absorbed by the soil	1535	1226	2039.6
Total present after absorption	2171	1862	2675.6
K_2O recovered	2138	1906	2628

It appears, therefore, that there has been redissolved practically all of the potash which had been absorbed, and, in addition, as much more as had been recovered by an acid digestion from the soil in its ordinary condition. In the case of the other two solvents this had not occurred; nevertheless the amounts which were redissolved were large, as they were from the untreated soils.

In still another series of experiments Peters used the same soil and, for solvents, water containing some one or another salt in solution. Both the ordinary untreated soil and that which had absorbed 2039.6 parts per million of K_2O were used; 100 grams of the soil were digested 3 days in 250 c. c. of the solution, and then quantities of the solution drawn off for determination. The results of these several determinations are brought together in the next table.

Amounts of potash absorbed by soil, recovered with salt solutions.

	Solution at start contained		SOLUTION AFTER DIGESTION CONTAINED OF					The soil had absorbed
			CaO.	MgO.	K_2O.	Na_2O.	NH_3.	
	In parts per million.							
	Sodium chloride solution.							
Treated soil	Na_2O	1443.6	140.0	2.4	458.8	1195.2	....	621 as Na_2O
Untreated soil....	Na_2O	1443.6	168.0	....	131.2	1335.6	....	270 as Na_2O
	Sodium nitrate solution.							
Treated soil	Na_2O	1123.2	268.4	2.4	393.2	878.8	....	611 as Na_2O
Untreated soil....	Na_2O	1123.2	155.2	....	100.4	1000.0	....	308 as Na_2O
	Ammonium chloride solution.							
Treated soil	NH_3	884.4	129.6	......	589.6	3.2	645.2	598 as NH_3
Untreated soil....	NH_3	884.4	313.6	....	100.4	25.2	686.4	495 as NH_3
	Ammonium nitrate solution.							
Treated soil	NH_3	866.0	128.8	....	582.0	9.6	638.4	569 as NH_3
Untreated soil....	NH_3	866.0	302.4	....	100.4	25.2	674.8	478 as NH_3
	Calcium chloride solution.							
Treated soil	CaO	1272.8	1069.6	7.2	516.0	70.0	....	508 as CaO
Untreated soil....	CaO	1272.8	1209.6	86.0	108.0	28.0	....	158 as CaO
	Calcium nitrate solution.							
Treated soil	CaO	1198.4	952.0	8.0	500.8	100.8	....	616 as CaO
Untreated soil....	CaO	1198.4	1120.0	118.0	115.6	33.2	....	196 as CaO
	Magnesium chloride solution.							
Treated soil	MgO	848.0	229.6	603.6	512.4	72.8	....	611 as MgO
Untreated soil....	MgO	848.0	358.4	758.8	92.4	54.8	....	223 as MgO
	Magnesium nitrate solution.							
Treated soil	MgO	926.8	216.8	690.4	489.6	98.0	....	591 as MgO
Untreated soil....	MgO	926.8	369.6	824.8	84.4	76.8	....	255 as MgO
	Distilled water.							
Treated soil	....	....	Trace	....	173.6	1.6	....	....

From this table it will be seen that when 250 c. c. of the various salt solutions named are used in digesting 100 grams of a soil which had previously absorbed 2040 parts per million of potash (K_2O) these salt solutions redissolved from 393.2 to 589.6

parts per million of the solution, which is equivalent to 983 to 1474 parts per million of the dry soil itself.

It is especially noteworthy that these salt solutions have been the means of dissolving very large amounts of potash from the untreated soil to which none had been added, except under field conditions. The amounts dissolved range between 211 and 328 parts per million of the soil, which means from 600 to 1000 lbs. per acre-foot. The sodium chloride produced the largest solution and the magnesium nitrate the least. Here, again, it would have been extremely helpful if an untreated sample had been washed in distilled water as one of the same series. In the case of the treated soil, which was washed in distilled water, there was redissolved, as shown in the last line of the table 173.6 parts per million of the solution of K_2O, or 434 parts per million computed on the soil; and this, when the solution was only 2.5 times the weight of the soil. It is, therefore, clear that however the potash was fixed in this soil, it was still, in a high degree, soluble in distilled water.

Referring to the right section of the table, p. 129, and comparing the amounts of soda, ammonia, lime and magnesia, which were absorbed from the solutions by the soil, with the amounts of potash brought into solution, as indicated in the K_2O column, it will be seen that the largest absorption of these bases has taken place where the largest solution of potash has occurred; nevertheless, the relative amounts are not such as would be expected by a simple chemical replacement.

OBSERVATIONS OF O. KULLENBERG.*

The soil used for the study of the absorption of potash was the same as that cited on p. 118. The salts used, the strengths of the solutions and the amounts of potash absorbed are given in the next table.

*Hoffman's Jahresbericht der Agrikultur-Chemie, 1865, p. 15.

Amounts of potash absorbed by the same soil from different strengths of different solutions of potash salts.

SOLUTIONS USED.	POTASH (K_2O) IN SOLUTION. Before absorption	After absorption.	Potash (K_2O) absorbed.
	In parts per million.		
Choride of potash (KCl.)	471	223.6	630
	942	538.8	970
	1884	1455.2	1084
	4708	4055.2	1652
	9416	8291.6	2832
Nitrate of potash (KO, NO_5)	471	249.2	566
	942	610.8	840
	1884	144.0	1097
	4708	4051.6	1658
	9416	8196.	3072
Sulphate of potash (KO, SO_3)	471	232.0	609
	942	556.0	977
	1884	1290.4	1496
	4708	3770.8	2360
	9416	8023.6	3503
Carbonate of potash (KO, CO_2)	471	188.0	719
	942	471.2	1489
	1884	996.4	2231
	4708	3476.2	3094
	9408	7296.0	3771
Phosphate of potash (2 KO, HO PO_5)	471	190.4	713
	942	438.4	1271
	1884	1043.6	2113
	4708	3396.8	3295
	9408	7422.8	5005

From the results of this table it is seen that not only have large amounts of potash been absorbed from all solutions but much larger amounts from the phosphates than from any others. Taking the mean amounts absorbed from the five solutions of each kind of salt, they stand as given in the next table.

Mean amounts of potash absorbed by one soil from different salt solutions.

Potassium chloride.	Potassium nitrate.	Potassium sulphate.	Potassium carbonate.	Potassium phosphate.
In parts per million of soil.				
1433.6	1446.6	1789.0	2260.8	2679.4
Percentage relation.				
53.50	53.96	67.18	84.34	100.00

From this comparison of Kullenberg's data it is seen that only little more than half the amounts of potash were absorbed from the very soluble chlorides and nitrates as from the phosphates.

The Absorption of Soda, Lime and Magnesia from Solutions by Soils.

Not so much work has been done relative to the absorption of these and other bases by soils as has been done upon potash and ammonia, but enough data has been accumulated to show, that under certain conditions, these bases, as well as potash and ammonia, may disappear from solutions when they are brought in contact with soils or powder-form bodies of similar nature.

Absorption of Soda.

OBSERVATIONS OF VOELCKER.*

To ascertain the absorptive power of soils for soda Voelcker operated upon 6 types with a solution of chemically pure sodium chloride. Into a glass-stoppered bottle he put 3500 grains of soil and 28000 grains of water solution of sodium chloride carrying 41.52 grains or 1482 parts per million of NaCl. The soil was in contact with the solution during 4 days, receiving occasional agitation throughout the interval.

A similar series was conducted with the same soils using KCl instead of NaCl, and the results of both are brought into a single table for comparison.

Amounts of potash and soda absorbed by 6 soils.

	Soda.	Potash.	Soda.	Potash.
	In parts per million.		Percentage relations.	
Stiff clay	1057	3970	100.00	100.00
Pasture land	1000	3758	94.60	94.66
Marly soil	996	3373	94.24	84.96
Calcareous soil	800	3578	75.68	90.13
Fertile sandy loam	620	2626	58.65	66.14
Sterile ferruginious sand	620	1465	58.65	38.91

*Journal Royal Agricultural Society, Second Series, Volume I, pp. 289-316.

It is seen, from the table, that (1) large amounts of both bases have been fixed by these soils; (2) much more potash than soda has been removed from solution; (3) there are large differences between the fixing powers of the different soils; (4) least potash was fixed by the sterile sand and next to it stands the other sandy soil; (5) the percentage relations between the amounts of the two bases fixed by the several soils are quite similar, the same soils fixing most and least of each base.

The same investigator conducted a similar experiment with a marly soil, using anhydrous sodium sulphate in the proportion of 44.93 grains to 28000 of water and 3500 of soil; the digestion covering 4 days. The amount of soda removed from the solution was at the rate of 1809 parts per million of soil or .1809 per cent.

OBSERVATIONS OF KULLENBERG.

This investigator made a series of studies relating to soda-fixation entirely similar to the one reported for potash, p. 130, and the results appear in the next table.

Amounts of soda absorbed from different solutions of the same soil.

Solution used.	Soda in solution, Na_2O. Before absorption.	Soda in solution, Na_2O. After absorption.	Soda absorbed, Na_2O.
	In parts per million.		
Chloride of soda (NaCl)	310.8	276.8	112
	622.0	545.2	229
	1244.0	1069.6	463
	3110.0	2712.4	1020
	6220.0	5579.6	1638
Nitrate of soda (NaO, NO_5.)	311	265.6	140
	622	541.6	228
	1244	1114.0	352
	3110	2765.2	889
	6220	5646.8	1460
Sulphate of soda ($NaO, SO_3 + 10 HO$.)	311	265.6	140
	622	546.4	216
	1244	1106.0	372
	3110	2781.2	849
	6220	5746.4	1211
Carbonate of soda ($NaO, CO_2 + 10HO$.)	311	252.8	172
	622	493.6	348
	1244	961.2	734
	3110	2476.8	1610
	6220	5408.8	2055
Phosphate of soda ($2NaO, HO, PO_5 + 24HO$)	311	233.6	220
	622	467.2	414
	1244	967.6	1718
	3110	2494.0	1567
	6220	5103.2	2819

From this table it is seen that large amounts of soda have been fixed by this soil and much more from the phosphate and carbonate solutions than from either of the others. It is also true of this series, as it was of that of Voelcker cited above, that much less soda has been fixed than was the case from the corresponding potash salts. The next table brings into comparison the potash and soda absorptions, as was done with Voelcker's data.

Mean amounts of potash and soda absorbed by the same soil from 5 corresponding salts.

	Soda.	Potash.	Soda.	Potash.
	In parts per million.		Percentage relations.	
Chlorides	692.2	1433.6	60.32	53.50
Nitrates	613.8	1446.6	53.45	53.96
Sulphates	557.6	1789.0	48.59	67.18
Carbonates	983.8	2260.8	85.73	84.34
Phosphates	1147.6	2679.4	100.00	100.00

This grouping of the data shows that practically the same percentage relation exists between the fixing of the bases from three of the five salts compared; but the chlorides, nitrates and sulphates stand in the opposite relation, as to quantity of bases fixed, there being least soda and most potash fixed from the sulphate solutions. This was not the case, however, in the instance cited above from Voelcker's work.

ABSORPTION OF LIME AND MAGNESIA.

We cite here the observations of Kullenberg,* which form a portion of work already cited, the method of procedure here being the same as for determinations made on the absorption of potash, soda and ammonia.

*Hoffman's Jahresbericht der Agrikultur-Chemie, 1865, pp. 17–18.

Amounts of lime and magnesia absorbed by the same soil from different strengths of solutions.

Solutions used.	Lime, CaO, and Magnesia, MgO, in Solution				Amounts Absorbed.	
	Before absorption.		After absorption.			
	CaO.	MgO.	CaO.	MgO.	CaO.	MgO.
	In parts per million.					
Chlorides of lime (CaCl) and of magnesia (MgCl)	280.0	200.0	258.8	135.2	118	184
	560.0	400.0	502.8	269.4	208	346
	1120.0	800.0	1038.0	628.8	270	450
	2800.0	2000.0	2702.8	1781.2	308	569
	5600.0	4000.0	5476.4	3614.8	374	985
Nitrates of lime (CaO, NO_5) and of magnesia (MgO, NO_5)..........	280.0	200.0	279.6	113.6	66	238
	560.0	400.0	514.0	260.4	180	371
	1120.0	800.0	1058.8	620.8	224	470
	2800.0	2000.0	2723.2	1716.4	257	731
	5600.0	4000.0	5494.8	3682.8	328	815
Sulphates of lime (CaO, SO_3 + 2HO) and of magnesia (MgO, HO, SO_3 + 6HO)	280.0	200.0	236.8	120.8	173	220
	560.0	400.0	488.8	264.0	243	362
	1120.0	800.0	1021.2	617.2	312	479
	....	2000.0	....	1715.2	....	734
	....	4000.0	....	3484.0	....	1312

If there is brought into one table the mean values for the absorption of the several bases by one and the same soil, and from the corresponding salts in solution, as found by Kullenberg, the results will appear as below:

Mean amounts of several bases absorbed by the same soil.

	Ammonia.	Potash.	Soda	Lime.	Magnesia.
	In parts per million of soil.				
Chlorides......................	640.2	1433.6	692.2	255.6	506.8
Nitrates	673.4	1446.6	613.8	211.0	525.0
Sulphates	792.0	1789.0	557.6	276.0	353.7
Carbonates	880.4	2260.8	983.8	....	....
Phosphates.......................	1411.0	2679.4	1147.6	....	....
Average of upper three....	701.9	1556.4	621.2	247.5	461.8

It is here seen that potash has been held back in the soil in much larger amounts than any other base, and lime to the smallest extent. If a percentage comparison of positive radicles is made, using the mean values of the three groups of determinations common to all bases, the values stand as here given

Percentage relation of the fixing power of one soil for bases.

K.	NH_4.	Na.	Mg.	Ca.
100.00	57.31	35.70	21.51	13.69

Absorptive Power of Soils for Phosphoric Acid.

OBSERVATIONS BY O. KULLENBERG.*

In the experiments here cited 100 grams of soil were digested 3 days in 250 c. c. of solution before the determinations were made the soil used being the same as that cited on p. 118. Three phosphate salts were used in these trials, and each in solutions having five concentrations. The results are next given.

Amounts of phosphoric acid absorbed by one soil from solutions of different kinds and strengths.

Solutions Used.	Phosphoric Acid in Solution, P_2O_5 — Before absorption.	Phosphoric Acid in Solution, P_2O_5 — After absorption.	Phosphoric acid absorbed, P_2O_5.
	In parts per million.		
Phosphate of potash ($2KO, HO, PO_5$)	710	491.2	553
	1420	1034.0	971
	2840	2198.8	1609
	7100	6137.2	2413
	14200	12834.8	3419
Phosphate of soda ($2NaO, HO, PO_5+24HO$)	710	600.0	281
	1420	1148.0	686
	2840	2322.0	1301
	7100	6197.6	2262
	14200	12891.6	3277
Phosphate of ammonia ($NH_4O, 2HO, PO_5$)	710	598.4	285
	1420	1276.4	365
	2840	2479.0	908
	7100	6340.0	1906
	14200	13150.8	2629

The mean fixation of phosphoric acid from the potash solutions is much larger than that from the other two salts, the percentage relations being:

From potash solutions.	From soda solutions.	From ammonia solutions.
1793	1561.4	1218.6
100.00	87.83	62.39

*Hoffman's Jahresbericht der Agrikultur-Chemie, 1865, p. 17.

OBSERVATIONS OF VOELCKER.*

Voelcker studied the absorption of soluble phosphates of five soils, using the super-phosphate, containing 37.20 per cent. of bone-earth, rendered soluble by acids; and the results obtained by him are brought together in the next table, where the ratio of water to soil, time of contact of the soil with the solution, the amounts of phosphoric acid absorbed, and left in the solution are given.

In the last two columns of the table there are also given the amounts of soluble phosphate the soil would contain if charged with 20 per cent. and 10 per cent. of the solutions after absorption had taken place, the amounts being expressed in parts per million of the dry soil.

Amounts of soluble phosphates absorbed by five soils.

Soil Used.	Ratio of soil to water.	Time of digestion.	Soluble Phosphate: Left in solution.	Soluble Phosphate: Absorbed by the soil.	Soluble Phosphate Given to Soil With: 20 per cent. of solution.	Soluble Phosphate Given to Soil With: 10 per cent. of solution.
		Days.	In parts per million.			
Red loam	1 to 2.5	1	1248.0	4627	249.6	124.8
	1 to 2.5	8	699.1	5998	139.8	69.9
	1 to 2.5	26	186.8	7282	37.4	18.7
Calcareous soil	1 to 2.5	1	315.7	6935	63.1	31.6
	1 to 2.5	8	32.76	7648	6.6	3.3
	1 to 2.5	26	trace.	7731	trace.	trace.
Stiff clay subsoil	1 to 2.5	1	1628.0	3676	325.6	162.8
	1 to 2.5	8	990.9	5268	198.2	99.1
	1 to 2.5	26	827.9	5676	165.6	82.8
Stiff clay surf'ce soil	1 to 4.2	1	985.7	4090	197.1	89.6
	1 to 4.2	8	771.4	4990	154.3	77.1
	1 to 4.2	17	305.7	6946	61.1	30.6
Light sandy soil	1 to 4.2	1	927.1	4292	184.5	92.3
	1 to 4.2	8	810.0	4784	162.0	81.0
	1 to 4.2	17	557.1	5856	111.4	55.7

It is seen from this table that, between the five soils treated, there is a clear and well marked difference in their powers of holding back the phosphoric acid, the calcareous soil exceeding all of the others in this rspect, both in absolute amount absorbed and in the rate of absorption. These differences are

*Journal Royal Agricultural Society, Volume XXIV, pp. 37–64.

brought out more clearly in the next table, where the differences are expressed percentagely, taking the absorption by the calcareous soil, at the close of each period, as 100.

Percentage differences in the fixing power of five soils for soluble phosphates.

Absorption Period.	Calcareous soil.	Red loam.	Stiff clay Surf'e soil.	Stiff clay subsoil.	Light sandy soil.
After 1 day	100.00	66.72	58.97	61.88	53.01
After 8 days	100.00	77.12	65.24	62.59	68.89
After 26 or 17 days	100.00	94.19	89.85	75.74	73.42

From this presentation of the data, it is seen that the fixing of soluble phosphates by the calcareous soil, during the first day, exceeds that of the other four soils by as much as 33.18 to 46.99 per cent; at the end of 8 days its effect is in excess from 22.88 to 37.41 per cent.; while, at the close of the last period, it is still in excess by as much as 5.81 to 26.58 per cent.

It is to be noted that, even at the end of 26 days, not all of the phosphate had been absorbed, although the quantity for the calcerous soil, found in the solution, is recorded as a "trace."

The unfortunate aspect of these observations, as indeed of all which have been cited, is the very large amounts of phosphates used in proportion to the soil.

Absorption by Soils of Sulphuric and Nitric Acids, and Chlorine.

It seems to have been quite the universal opinion of the earlier investigators along these lines that little or none of the negative radicles are absorbed by soils, with the exception of phosphoric and silicic acids. It is true, however, that some indications of absorption of sulphuric acid and of chlorine have been observed, but the tendency was to attribute them either to errors of observation or else to the formation of ammonium chloride or sulphate, in which cases (Voelcker's instances) they were regarded as being lost on heating after evaporation.

In our own experience, however, as will be given later, there appears little question but that nitric acid and sulphuric acid,

and possibly even chlorine to a small extent, and under some conditions, are removed from solution or retained by soil surfaces.

Comparative Study of the Absorptive Power of Eight Soil Types.

From the observations which have been cited, relative to the absorptive power of soils for different water-soluble salts, and in regard to the recovery of them after absorption has taken place, it is abundantly clear that here is an extremely important subject which has, as yet, received far too little attention, either as to its nature, origin, extent or relation to differences in soil fertility.

The results which have been cited show unmistakably, not only that the absorptive power of soils for plant food ingredients is large, but they indicate that wide differences in this power may exist between different soils. Moreover, the results which have been presented, in Bulletins "B" and "C," regarding the differences in the amounts of water-soluble salts which may be recovered, by water alone, during very brief periods of contact, and the relation of these amounts to yields, make it extremely pertinent to inquire whether or not differences in the immediate productive capacities of soils may not be indicated by, if not in part due, to differences in the amounts of plant food materials which have, from time to time, been absorbed from solutions coming in contact with them. Not only this, but it is equally important to ascertain whether or not good, as contrasted with poor, soil management does not bring about, through one and another means, a gradual upbuilding of the absorbed essential ingredients of plant food. In other words, if the farmer does not, in fact, by good handling and good feeding, cause the skeleton of the soil to become clothed, through this absorption process, with materials which make it better capable of nourishing crops.

In view of the fact that the water-soluble salts in 8 soils were being critically studied in relation to the yields of crops from them, it seemed especially important to compare their absorptive powers for water-soluble salts also, and a preliminary study was made.

METHODS OF OBSERVATION.

The aim in this preliminary work, has been, first of all, to secure a body of observations upon mixed or complex solutions, such as the dissolved portions of stable manure, fertilizers and soil solutions are. Since it is true that soils are all of the time, so long as they are moist and exposed to climatic conditions, being treated with a mixed solution moving either capillary or by gravitation, it appeared best to make the first observations with solutions of a similar nature and not so concentrated, as most of the solutions employed in the cases which have been cited.

In all cases the volume of the solution used has been equal to five times the water-free weight of the samples treated and generally 600 c. c. of solution and 120 grams of soil have been taken. Most of the observations have been made with short periods of contact of the solution with the soil, this being made sometimes by shaking in bottles and sometimes by percolation, using the arrangement described in Bulletin "B," p. 81.

The soils have been examined for the amounts of water-soluble salts which could be recovered from them by washing three minutes in distilled water, and the amounts so recovered have been added to the amounts which were added with the solution to the duplicate samples of soil treated, and the absorption has been taken as the difference between the amounts remaining in the solution and those originally present, plus those shown to be present in the soil before treatment. Only colorimetric methods have been used in determining the changes which occurred in the solution.

ABSORPTION OF SALTS BY JANESVILLE LOAM.

The first series of observations was made on the surface four feet of the Janesville Loam, one sample from each of the five fertilizations, thus giving five determinations for the same soil type at each depth. The full set of data are given in this case, so as to indicate the character of fluctuations which occurred in the results obtained.

The solution used was prepared gravimetrically from stock chemicals to contain approximately the following amounts:

Approximate composition of solution used.

K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	Cl
In parts per million of solution.						
25	25	10	40	20	40	30

This solution was analyzed in duplicate with those obtained from the soils and the average of the two analyses taken to represent the composition of the solution.

Since the amount of solution applied to the soil was five times the weight of the soil, the total salts added to the soil in this way, in case they were all absorbed, would be, when expressed in parts per million of the soil, five times that found in the solution.

The treatment of the samples consisted in weighing into stoppered bottles 120 grams of the dry soils and 4 grams of carbon black, to decolorize the solutions. To each sample was then added 600 c. c. of solution and vigorously shaken during 3 minutes; and then allowed to stand 24 hours, but shaken, during 3 minutes, 10 times during that interval.

The results which were obtained are given in the table which follows, together with the amounts obtained from duplicate samples, using distilled water instead of the solution.

Amounts of water-soluble salts recovered from Janesville Loam by washing in a salt solution and in distilled water.

		K.	Ca.	Mg.	NO_3.	HPO_4	SO_4	HCO_3	Cl.	SiO_2.
		In parts per million of dry soil.								
		Recovered with salt solution.								
Nothing added	1 ft.	40.70	195.00	51.20	145.20	11.80	264.00	22	140	70.60
5 tons manure added.		62.90	165.00	49.64	140.00	18.40	260.00	24	146	66.00
10 tons manure added.		48.00	165.00	49.64	145.20	13.00	256.00	32	150	69.80
15 tons manure added.		54.40	157.50	50.34	132.00	18.20	268.00	18	150	60.10
300 lbs. guano added...		50.60	155.00	48.90	181.60	16.80	252.00	20	152	67.20
Average..............		51.32	167.50	49.94	148.80	15.64	260.00	23.2	147.6	66.74
Nothing added	2 ft	53.00	165.00	52.68	168.80	17.40	236.00	2	150	74.10
5 tons manure added.		44.40	162.50	51.80	161.60	15.60	256.00	–4	148	78.00
10 tons manure added.		50.00	155.00	54.74	168.80	15.00	244.00	–2	150	78.80
15 tons manure added.		56.20	150.00	48.90	161.60	11.60	256.00	–4	150	79.50
300 lbs. guano added...		34.80	145.00	49.64	158.00	19.40	264.00	–4	152	74.50
Average.....		47.68	155.50	51.56	163.76	15.76	251.20	–2.4	150	76.98
Nothing added	3 ft.	58.10	145.00	49.64	196.40	11.00	252.00	2	152	99.30
5 tons manure added.		55.40	147.50	50.34	172.80	5.00	236.00	–2	152	90.80
10 tons manure added.		42.80	132.50	50.34	191.20	9.00	220.00	–4	150	90.40
15 tons manure added.		53.00	127.50	49.54	172.80	7.60	248.00	–4	148	94.30
300 lbs. guano added...		55.40	135.00	51.20	196.40	15.60	244.00	6	152	87.70
Average..............		52.94	137.50	50.21	185.92	9.64	240.00	–0.4	150.8	92.50
Nothing added	4 ft.	37.50	125.00	50.34	181.60	11.20	224.00	–8	150	100.90
5 tons manure added.		37.30	142.50	55.22	177.20	11.20	208.00	4	150	99.70
10 tons manure added.		39.00	150.00	52.68	186.40	14.80	216.00	–4	150	99.30
Average.		37.93	139.07	52.75	181.73	12.40	216.00	–2.67	150	99.97
Known solution		21.20	20.50	9.51	28.00	23.86	41.60	–1.6	29.2	0.00
Known solution		21.04	22.00	9.78	27.44	23.94	40.00	–1.6	30.0	0.00
Average...		21.12	21.25	9.645	28.72	23.90	40.80	–1.6	29.6	0.00
		Recovered with distilled water.								
Nothing added .	1 ft.	11.76	77.50	24.45	88.60	24.60	116.00	20	4	50.13
5 tons manure added.		20.00	78.75	25.93	90.80	16.20	126.00	16	2	54.79
10 tons manure added.		18.08	78.75	23.46	79.00	20.20	98.00	10	2	40.82
15 tons manure added.		17.12	75.00	21.95	82.60	19.40	112.00	18	2	42.06
300 lbs. guano added...		19.12	61.25	25.60	95.60	19.20	128.00	14	2	48.42
Average..............		17.22	74.25	24.28	87.32	19.92	116.00	15.6	2.4	47.24
Nothing added	2 ft.	18.40	55.00	18.02	39.28	16.40	136.00	2	0	59.29
5 tons manure added.		12.28	45.00	16.64	40.96	15.60	122.00	2	0	49.82
10 tons manure added.		13.32	48.00	15.56	33.44	14.60	122.00	–2	0	49.04
15 tons manure added.		15.12	51.00	17.47	31.92	24.20	108.00	24	0	47.80
300 lbs guano added...		14.84	45.00	15.16	32.64	22.00	118.00	10	0	48.58
Average..............		14.79	48.80	16.57	35.65	18.56	121.20	7.2	0	50.91
Nothing added	3 ft.	28.56	41.00	19.45	36.32	27.60	136.00	–8	0	67.67
5 tons manure added.		20.00	37.50	15.16	41.52	16.80	118.00	10	0	56.18
10 tons manure added.		19.52	35.50	16.40	35.84	20.00	112.00	8	0	59.60
15 tons manure added.		17.76	35.00	15.04	26.96	23.40	110.00	2	0	59.13
300 lbs. guano added...		18.08	33.00	15.16	36.32	21.60	104.00	6	0	57.27
Average..............		20.78	36.40	16.44	35.39	21.88	116.00	3.6	0	59.97
Nothing added	4 ft.	17.24	24.00	16.82	56.96	13.80	89.00	10	0	66.58
5 tons manure added.		21.20	30.00	16.18	55.84	16.20	75.00	10	0	64.72
10 tons manure added.		18.56	29.50	17.12	55.84	26.40	91.00	12	0	67.05
Average..............		19.00	27.83	16.71	56.21	18.80	85.10	10.67	0	66.12

From the data in the table, it will be seen what variations have occured in the individual determinations of samples of the same soil type, taken from different portions of the same field, and from different depths, both when washed in the salt solution and when washed in the distilled water. The duplicate determinations made on the salt solution will show what should be allowed for the methods themselves, when working with such concentrations as these have been.

For purposes of comparing the absorptive effects of these soils it will be proper to use the averages of the five determinations for each depth, and this has been done in the next table:

Amounts of salts absorbed in 24 hours by 120 grams of Janesville Loam from 600 c. c. of a salt solution.

	K.	Ca.	Mg.	NO_3.	HPO_4	SO_4.	HCO_3	Cl.	SiO_2.
	In parts per million of dry soil.								
	Surface foot.								
In soil at start...........	17.22	74.25	24.28	87.32	19.92	116.00	15.60	2.40	47.24
Added with solution	105.60	106.25	48.23	143.60	119.50	204.00	−8.00	148.00	0.00
Total present....	122.82	180.50	72.51	230.92	139.42	320.00	7.60	150.40	47.24
Amount recovered.......	51.32	167.50	49.94	148.80	15.64	260.00	23.20	147.60	66.74
Change in soil...........	71.50	13.00	22.57	82.12	123.78	60.00	−15.60	2.80	−19.50
	Second foot								
In soil at start	14.79	48.80	16.57	35.65	18.56	121.20	7.20	0.00	50.91
Added with solution.....	105.60	106.25	48.23	143.60	119.50	204.00	−8.00	148.00	0.00
Total present............	120.39	155.05	64.80	179.25	138.06	325.20	−.80	148.00	50.91
Amount recovered.......	47.68	155.50	51.56	163.76	15.76	251.20	−2.40	150.00	76.98
Change in soil.........	72.71	−.45	13.24	15.49	122.30	74.00	1.60	−2.00	−26.07
	Third foot.								
In soil at start...........	20.78	36.40	16.44	35.39	21.88	116.00	3.60	0.00	59.97
Added with solution.....	105.60	106.25	48.23	143.60	119.50	204.00	−8.00	148.00	0.00
Total present............	126.38	142.65	64.67	178.99	141.38	320.00	−4.40	148.00	59.97
Amount recovered.......	52.94	137.50	50.21	185.92	9.64	240.00	−0.40	150.80	92.50
Change in soil	73.44	5.15	14.46	−6.93	131.74	80.00	−4.00	−2.80	32.53
	Fourth foot.								
In soil at start...........	19.00	27.83	16.71	56.21	18.80	85.10	10.67	0.00	66.12
Added with solution.....	105.60	106.25	48.23	143.60	119.50	204.00	−8.00	148.00	0.00
Total present	124.60	134.08	64.94	199.81	138.30	289.10	2.67	148.00	66.12
Amount recovered......	87.93	139.07	52.75	181.73	12.40	216.00	−2.67	150.00	99.97
Change in soil	86.67	−4.99	12.19	18.08	125.90	73.10	−5.3	−2.00	−33.85

From this table of averages it will be observed the data show less phosphoric acid has been recovered from each of the four depths than was recovered from the soil when washed

in distilled water, while at the same time more silica has been indicated by the method. If the reliability of the method is admitted, it follows that treating this soil with the salt solutions used has resulted in fixing in the soil not only all the phosphoric acid added but a considerable per cent. of that which could be recovered with distilled water in contact but three minutes; the lime, however, appears to have suffered but little change.

Potash has become fixed in increasing amounts with the depth and in each case the soil has taken on from three to four times the quantity recovered with distilled water; while of magnesia the amounts absorbed from the solution are in no case quite equal to those originally recovered with the distilled water.

The absorption of SO_4 has been large, and the results, in themselves, also indicate an absorption of nitric acid, although there is more reason to doubt these values on account of the large amounts of chlorine present which had to be removed before the determinations could be made, and on account of the possibility and even probability of denitrification having taken place.

The chlorine, like the lime, remains practically unchanged and was introduced with it, but lime was also added as a phosphate, the salts used being $CaHPO_4$, $2HO$; $MgSO_4$, $4H_2O$; $CaCl_2$ and KNO_3.

ABSORPTION OF SALTS BY THE HAGERSTOWN LOAM.

Another series of observations was made in the same manner as described in the last section but upon only two sets of samples from each depth, instead of from five, as was the case with the Janesville Loam. A new solution, however, was prepared but intended to be approximately identical with the last.

The results obtained with this soil are given in the next table.

Salts recovered from Hagerstown Loam after digestion in a salt solution during 24 hours.

		K.	Ca.	Mg.	NO_3.	HPO_4	SO_4.	HCO_3	Cl.	SiO_2.
		In parts per million of dry soil.								
		Surface foot.								
In soil at start	A.	23.84	68.75	28.06	90.80	6.00	134.00	34.00	0.00	23.90
Added with solution	A.	101.60	104.00	51.20	101.00	122.50	180.00	0.00	151.00	0.00
Total present.......	A.	125.44	172.75	79.26	191.80	128.50	314.00	34.00	151.00	23.90
Amount recovered..	A.	30.50	275.00	49.64	133.50	8.50	176.00	18.00	148.00	32.70
Change in soil.. ...	A.	94.74	−102.25	29.62	58.30	120.00	138.00	16.00	3.00	−8.80
In soil at start......	B.	20.80	72.50	22.82	84.40	5.40	138.00	24.00	0.00	26.10
Added with solution	B.	101.60	104.00	51.20	101.00	122.50	180.00	0.00	151.00	0.00
Total present.......	B.	122.40	176.50	74.02	185.40	127.90	318.00	24.00	151.00	26.10
Amount recovered..	B.	25.60	240.00	44.44	144.50	5.80	162 00	20.00	150.00	27.80
Change in soil......	B.	96.80	− 63.50	29.58	40.90	122.10	156.00	4.00	1.00	−1.70
		Second foot.								
In soil at start......	A.	11.92	37.00	13.46	17.72	13.60	43.50	14.00	0.00	24.10
Added with solution	A.	101.60	104.00	51.20	101.00	122.50	180.00	0.00	151.00	0.00
Total present.......	A.	113.52	141.0,	64.66	118.72	135.10	223.50	14.00	151.00	24.10
Amount recovered..	A.	59.60	250.00	46.28	139.50	10.90	288.00	78.00	152.00	33.00
Change in soil......	A.	53.92	−109.00	17.36	− 21.78	124.20	−44.50	−64.00	−1.00	−8.90
In soil at start... ..	B.	9.56	36.00	11.41	22.72	11.60	37.50	20.00	0.00	20.50
Added with solution	B.	101.60	104.00	51.20	101.00	122.50	180.00	0.00	151.00	0.00
Total present.......	B.	111.16	140.00	62.61	123.72	124.10	217.50	20.00	151.00	20.50
Amount recovered..	B.	58.80	260.00	60.16	159.50	13.20	260.00	48.00	152.00	33.50
Change in soil	B.	53.36	−120.00	2.45	−35.78	110.90	−42.50	−28.00	−1.00	−13.00
		Third foot								
In soil at start......	A.	9.76	23.00	13.46	49.10	7.80	5.00	5.00	2.00	34.00
Added with solution	A.	101.60	104.00	51.20	101.00	122.50	180.00	0.00	151.00	0.00
Total present	A.	111.36	127.00	64.66	150.10	130.30	185.00	5.00	153.00	34.00
Amount recovered..	A.	31.00	137.50	42.80	137.50	11.40	12.50	6.00	146.00	64.80
Change in soil	A.	79.66	−10.50	21.86	12.60	128.90	172.50	−1.00	7.00	−30.80
In soil at start......	B.	7.50	22.00	12.68	44.30	8.00	5.00	16.00	12.00	28.40
Added with solution	B.	101.60	104.00	51.20	101.00	122.50	180.00	0.00	151.00	0.00
Total present.......	B.	109.10	126.00	63.88	145.30	130.50	185.00	16.00	163.00	28.40
Amount recovered.	B.	25.40	172.50	36.80	154.00	13.20	17.00	6.00	150.00	49.30
Change in soil	B.	83.70	−46.50	27.08	−8.70	127.30	168.00	10.00	13.00	−20.90
		Fourth foot.								
In soil at start	A.	8.00	12.00	15.22	47.80	3.60	3. 00	6.00	10.00	36.40
Added with solution	A.	101.60	104.00	51.20	101.00	122.50	180.00	0.00	151.00	0.00
Total present.......	A.	109.60	116.00	66.42	148.80	126.10	183.00	6.00	161.00	36.30
Amount recovered..	A.	43.60	104.00	55.20	168.50	17.60	2.00	0.00	138.00	71.00
Change in soil	A.	66.00	12.00	11.22	−19.70	108.50	181.00	6.00	23.00	−34.60
In soil at start.....	B.	8.48	12.75	13.70	36.30	.80	3.00	16.00	4.00	36.40
Added with solution	B.	101.60	104.00	51.20	101.00	122.50	180.00	0.00	151.00	0.00
Total present.... .	B.	110.08	116.75	64.90	137.30	123.30	183.00	16.00	154.00	36.40
Amount recovered..	B.	38.70	114.00	43.90	162.50	18.80	14.00	6.00	150.00	58.30
Change in soil......	B.	71.38	2.75	21.00	−15.20	105.50	169.00	10.00	4.00	−21.80

From the data in this table it will be seen that the results are in some ways very different from those just cited. In but one case was quite all the phosphoric acid removed from the solution but the solution was a little stronger as used on this soil. Silica was more soluble in the salt solution than in distilled water, but not as much so as in the Janesville Loam, except in the third and fourth feet.

The lime has behaved very differently, except in the fourth foot, very large amounts of it going into solution in the first and second feet, while in the fourth absorption has occurred.

The different depths have absorbed the potash very unequally, the surface foot taking nearly double what the second has taken.

In the case of the sulphuric acid, too, there is a strong contrast, very much larger amounts having been absorbed, except in the second foot, where a notable amount has gone into solution from the soil itself.

If it be held that the comparison should be made between the amounts added to the soil in the solution and the amounts recovered from the solution afterwards, of course, quite different statements would be made, but we see little reason to ignore the readily water-soluble salts present in the soil at the start.

Another set of soil samples, duplicates of those just described, were treated in the same way, except that contact of the solution with the soil was continued 72 hours instead of 24, the identical solution being used.

The results obtained are recorded in the next table.

Salts recovered from Hagerstown Loam after digestion in a salt solution during 72 hours.

		K.	Ca.	Mg.	No_3	HPO_4	SO_4.	HCO_3.	Cl.	SiO_2
		In parts per million of dry soil.								
		Surface foot.								
In soil at start......	A.	23.84	80.00	28.04	80.80	10.60	140.00	36.00	0.00	25.00
Added with solution.	A.	107.70	104.00	48.94	98.75	144.00	202.00	27.00	158.00	0.00
Total present.... ...	A.	131.54	184.00	76.98	179.55	154.60	342.00	63.00	158.00	25.00
Amount recovered...	A.	78.80	205.00	57.04	66.00	17.50	300.00	170.00	164.00	35.30
Change in soil.......	A.	52.74	−21.00	19.94	113.55	137.10	42.00	−107.00	−6.00	−10.30
In soil at start.......	B.	20.80	73.75	22.82	68.60	12.80	120.00	36.00	0.00	21.30
Added with solution.	B.	107.70	104.00	48.94	98.75	144.00	202.00	27.00	158.00	0.00
Total present........	B.	128.50	177.75	70.96	167.35	156.80	322.00	63.00	158.00	21.30
Amount recovered...	B.	57.40	245.00	56.12	77.20	18.50	296.00	120.00	160.00	33.40
Change in soil.......	B.	71.10	−67.25	14.84	90.15	138.30	26.00	−57.00	−2.00	−12.10
		Second foot.								
In soil at start.......	A.	11.92	49.00	13.46	23.44	10.80	39.50	18.00	0.00	17.70
Added with solution.	A.	107.70	104.00	48.94	98.75	144.00	202.00	27.00	158.00	0.00
Total present........	A.	119.62	153.00	62.40	122.19	154.80	241.50	45.00	158.00	17.70
Amount recovered...	A.	23.90	170.00	43.90	139.50	11.80	166.00	30.00	158.00	26.70
Change in soil	A.	95.72	−17.00	18.50	−17.41	143.00	75.50	15.00	0.00	−9.00
In soil at start..... .	B.	9.56	45.00	11.41	23.30	9.80	39.00	20.00	0.00	19.90
Added with solution.	B.	107.70	104.00	48.94	98.75	144.00	202.00	27.00	158.00	0.00
Total present........	B.	117.26	149.00	60.39	122.05	153.80	241.00	47.00	158.00	19.90
Amount recovered...	B.	21.76	197.50	45.04	134.50	9.00	176.00	28.00	154.00	27.60
Change in soil.......	B.	95.50	−48.50	15.35	−12.45	144.80	65.00	19.00	4.00	−7.70
		Third foot.								
In soil at start.......	A.	9.76	24.50	13.46	14.28	6.40	19.00	24.00	2.00	30.20
Added with solution.	A.	107.70	10.40	48.94	98.75	144.00	202.00	27.00	158.00	0.00
Total present........	A.	117.46	128.50	62.44	113.03	150.40	221.00	51.00	160.00	30.20
Amount recovered...	A.	24.00	132.50	37.52	119.20	12.30	70.00	6.00	154.00	42.30
Change in soil.......	A.	93.46	−4.00	24.92	−6.17	138.10	151.00	45.00	6.00	−12.10
In soil at start.......	B.	7.50	27.50	12.68	45.40	7.00	4.50	6.00	4.00	29.20
Added with solution.	B.	107.70	104.00	48.94	98.75	144.00	202.00	27.00	158.00	0.00
Total present........	B.	115.20	131.50	61.62	144.15	151.00	206.50	33.00	162.00	29.20
Amount recovered...	B.	40.70	110.00	34.24	154.40	14.70	8.50	4.00	154.00	53.20
Change in soil.......	B.	74.50	21.50	27.38	−10.25	136.30	198.00	29.00	8.00	−24.00
		Fourth foot.								
In soil at start.......	A.	8.00	18.85	15.22	35.70	3.60	6.50	24.00	6.00	34.00
Added with solution.	A.	107.70	104.00	48.94	98.75	144.00	202.00	27.00	158.00	0.00
Total present........	A.	115.70	122.85	64.16	134.45	147.60	208.50	51.00	164.00	34.00
Amount recovered...	A.	42.10	110.00	36.04	146.50	4.40	24.00	−4.00	154.00	64.00
Change in soil.......	A.	73.60	12.85	28.12	−12.05	143.20	184.50	55.00	10.00	−30.00
In soil at start.......	B.	8.48	14.50	13.70	49.10	.80	4.00	14.00	4.00	32.90
Added with solution	B.	107.70	104.00	48.94	98.75	144.00	202.00	27.00	158.00	0.00
Total present........	B.	116.18	118.50	62.34	147.85	144.80	206.00	41.00	162.00	32.90
Amount recovered...	B.	67.80	90.00	36.80	159.50	16.80	8.50	4.00	154.00	77.60
Change in soil......	B.	48.38	28.50	25.54	−11.65	128.00	197.50	37.00	8.00	−44.70

It will be clear from this table that some notable changes have occurred during the longer interval of digestion. They may be best seen by averaging the duplicate determinations and combining these, as given in the next table.

Mean amounts of salts absorbed by the Hagerstown Loam from a salt solution during 24 and 72 hours.

	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million of dry soil.								
	Change in surface foot.								
After 24 hours	95.77	—82.88	29.60	49.60	121.10	147.00	10.00	2.00	—5.25
After 72 hours	61.92	—44.13	17.39	101.85	137.10	34.00	—82.00	—4.00	—11.20
	Change in second foot.								
After 24 hours	53.64	—11.45	9.91	—28.78	117.55	—43.50	—46.00	—1.00	--10.95
After 72 hours	95.61	—32.75	16.93	—14.93	143.90	70.35	17.00	2.00	—8.35
	Change in third foot.								
After 24 hours	81.68	--28.50	24.47	1.95	128.10	170.25	4.50	10.00	—25.85
After 72 hours	83.98	8.75	25.65	—8.21	137.20	174.50	37.00	7.00	—18.05
	Change in fourth foot.								
After 24 hours	68.69	7.38	16.11	--17.45	107.00	175.00	8.00	13.50	-28.20
After 72 hours	60.99	20.68	26.83	--11.80	135.60	191.00	46.00	9.00	—37.35

The data of this table make it appear that these soils have increased their content of phosphoric acid, by absorption from the solution during 72 hours, adding to what they already had nearly 140 parts per million for all four feet; but at the same time they appear to have lost from 8 to 37 parts of silica.

Sulphuric acid, contrary to the observations of the earlier investigators cited, has been absorbed in very large amounts by all four feet at the end of 72 hours, although, at the end of 24 hours, the duplicate determinations on the second foot showed a solution from that soil of 44 and 42 parts per million.

The large apparent absorption of nitric acid by the soil of the surface foot may be due to denitrification.

The first, second and third feet lost lime, as would be expected from earlier observations, until the end of 24 hours and, except the third foot, to the end of 72 hours. The fourth foot, however, absorbed an increasing amount to the end.

Both potash and magnesia were absorbed and the potash in largest amounts, as was to be expected; but, after 24 hours, the surface foot gave back to the solution again large amounts of both bases.

While the indicated absorption of chlorine is small, compared with other things, we believe it is too large to be set aside as due to errors of method and irregularities in manipulation.

ABSORPTION OF SALTS BY WASHED SAND.

A quantity of a rather coarse, white sand, composed chiefly of quartz grains, was subjected to thorough washing under the hydrant during 12 hours, after which it was dried at 110° C, and then three times washed in distilled water with drying between each washing, after draining away all the water which would readily pass off. Samples of this sand were treated in the same manner as the Hagerstown Loam had been treated and with the same solutions, using five times the weight of the sand in each trial. The digestion was done in duplicate, two samples remaining in contact with the solution 24 hours and the other two during 72 hours.

In order that the conditions under which the sand was placed might be as nearly identical with those of the soil as possible, 4 grains of the carbon black used in rendering solutions colorless were also added to the sand. At the same time two blanks with the carbon black alone in the same solution were run, but in neither of these was there any indication of absorption.

The results secured from the sand appear in the next table.

Amounts of salts absorbed by clean water-washed sand during 24 and 72 hours.

	K.	Ca.	Mg.	NO_3.	HPO_4	SO_4.	HCO_3	Cl.	SiO_2.
	In parts per million of dry sand.								
	Absorbed during 24 hours.								
In sand at start..........	4.04	4.00	5.03	.48	7.20	13.00	6.00	0.00	2.50
Added with solution	101.60	104.00	51.20	101.00	122.50	180.00	0.00	151.00	0.00
Sum..................	105.64	108.00	56.23	101.48	129.70	193.00	6.00	151.00	2.50
	In first trial.								
Amount recovered	101.60	140.00	51.86	94.50	125.10	208.00	0.00	148.00	0.00
Change in sand..........	4.04	- 32.00	4.37	6.98	4.60	−15.00	6.00	3.00	−2.50
	In second trial.								
Amount recovered.......	104.00	145.00	51.86	98.75	122.50	212.00	0.00	150.00	0.00
Change in sand..........	1.64	−37.00	4.37	2.73	7.20	−19.00	6.00	1.00	−2.50
Average.......	2.82	−34.50	4.37	4.96	5.90	−17.00	6.00	2.00	−2.50
	Absorbed during 72 hours.								
In sand at start..........	4.04	4.00	5.03	.48	7.20	13.00	6.00	0.00	2.50
Added with solution	107.70	104.00	48.94	98.75	144.00	202.00	27.00	158.00	0.00
Sum	111.74	108.00	53.97	99.23	151.20	215.00	33.00	158.00	2.50
	In first trial.								
Amount recovered.......	122.00	114.00	46.92	103.25	99.80	220.00	52.00	154.00	36.40
Change in sand..........	−10.26	−6.00	7.05	−4.02	51.40	−5.00	−19.00	4.00	−33.90
	In second trial.								
Amount recovered.......	108.40	120.00	50.34	87.50	117.60	224.00	8.00	158.00	20.50
Change in sand..........	3.34	-12.00	3.63	11.73	33.60	−9.00	25.00	0.00	−18.00
Average.............	−3.46	- 9.00	5.34	3.86	42.50	−7.00	3.00	2.00	25.95

From the data of this table it is clear that this washed sand has effected but a very small absorption of salts from the solution used when compared with the absorption by the Hagerstown Loam, and they serve to emphasize the point already made, that very strong differences may exist in the absorptive power of different soils and that, until the reverse is proven by careful observation to be true, we must expect to find that soils having a high absorbing power are capable, under favorable conditions, of giving larger yields than those having small absorbing power, and there can be no question regarding the desirability of carrying out suitable researches to establish what relation there may

be between yields and the absorptive power of soils for salts carried in solutions which are brought in contact with them.

The results of these observations on the sand are in several ways quite in accord with those obtained from the Hagerstown Loam. To illustrate, during the shorter digestion, more lime went into solution during the 24 hours than during the 72 hours, as was the case with the Hagerstown Loam. More SO_4 went into solution from the sand during the shorter period and less was fixed by the soil referred to. In the case of the potash, too, both in the surface foot and in the fourth foot of the Hagerstown Loam, there was a smaller absorption associated with the longer period, and there are indications that this was also true of the sand. We have no reason to think that these relations may have resulted from some systematic error affecting all the observations, but it is, perhaps, not impossible that such may have been the case.

The observations here cited are in some ways quite in accord with some of the observations and remarks of Voelcker,* made in connection with his study of the absorptive power of different soils on liquid manures, and there have been presented in the next table two sets of his determinations made upon two quite different soils, with a view to ascertaining their relative absorptive powers.

The two cases chosen are the soil of a permanent pasture and a poor, sandy soil from the neighborhood of Cirencester, containing:

	Sandy soil.	Permanent pasture.
Organic matter	5.38 per cent.	11.70 per cent.
Clay	4.57 per cent.	48.39 per cent.
Lime	.25 per cent.	1.54 per cent.
Sand	89.82 per cent.	35.95 per cent.

*Journal Royal Agricultural Society, Volume XX, 1859, pp. 141–148.

The final results of Voelcker's determinations are given in the next table.

Composition of liquid manure before and after filtration through two soils.

One Imperial Gallon Contains	Before filtration. Grains.	After Filtration.		Change.	
		Permanent pasture. Grains.	Sandy soil. Grains.	Permanent pasture. Grains.	Sandy soil. Grains.
Water and volatile ammonia compounds containing........	69888.14	69856.85	69892.41	−31.29	+42.70
Am'nia as carbonate and muriate	(35.58)	(20.83)	(33.15)	−14.75	− 2.43
Organic matters....................	20.59	31.14	25.06	+10.55	+ 4.47
Containing nitrogen	(1.49)	(2.20)	(1.40	+ .71	− .09
Inorganic matters consisting of..	(91.27)	(112.01)	(82.53)	+20.74	− 8.74
Soluble silica.....	2.34	3.06	5.10	+ .72	+ 2.76
Insoluble siliceous matter.......	....	2.97	.. ..	+ 2.97	....
Oxide of iron	....	....	1.39	....	+ 1.39
Lime	11.48	25.21	8.03	+13.73	− 3.35
Magnesia	2.87	2.87	.74	0.00	− 2.13
Potash	16.92	5.19	12.01	−11.73	− 4.91
Chloride of potassium...	2.47	4.88	0.00	+ 2.14	− 2.74
Chloride of sodium...............	40.35	39.23	39.25	− 1.12	− 1.10
Phosphoric acid....	4.83	1.74	1.92	− 3.09	− 2.91
Sulphuric acid	3.94	2.73	3.67	− 1.21	− .27
Carbonic acid and loss...........	5.80	24.13	7.90	+18.33	+ 2.10

The amount of soil used in these cases was 20,000 grains. The 70,000 grains of solution contained 69 parts per million of phosphoric acid and from this solution the pasture land increased its phosphoric acid content 154.5 parts per million and the sandy soil 145.5 parts. From a solution containing 241.7 parts per million of potash the pasture land absorbed 586.5 parts per million of itself and the sandy soil 245.5 parts per million.

It will be further observed that the manure solution reduced the amount of lime carried by the pasture land, taking into itself 13.73 grains, whereas the sandy soil exerted an opposite effect, withdrawing 3.35 grains. The two soils differ, therefore, in their effects upon this solution by the sum of these amounts, or 17.08 grains; one of them yielding from itself 686.5 and the other taking to itself 167.5 parts per million of its dry weight. One of these soils showing that it possessed so much lime, in soluble form, that it could, under the conditions imposed, give up about a ton per acre-foot; while the other was in so different a condition that it must draw from the same solution and fix about its grains, more than 500 lbs. of lime per acre-foot. With differences like these between the effects of two soils upon one and the

same solution, and with the admitted dependence of crops upon soluble matter in soils, it is, perhaps, not strange that Voelcker should describe his least absorptive sample as taken from a "very infertile soil."

ABSORPTION OF SALTS BY EIGHT SOIL TYPES FROM A DILUTE MANURE SOLUTION.

After having washed the samples of 8 soil types eleven times in distilled water, as described in Bulletin "B," p. 81, the same samples were washed with a prepared manure solution to which a quantity of potassium nitrate was added in order to have (1) a considerable amount of potash in the solution, and (2) to study the effect of these soils upon nitric acid in the presence of other ingredients of such a solution. The potassium nitrate was not added until everything was ready to make the washing, this precaution being taken to avoid denitrification.

The manure solution was prepared by choosing such an amount as would be equivalent to a dressing of 15 tons of stable manure per acre, allowing the surface foot of soil to weigh 3,000,000 lbs.; the manure to be incorporated with one-half the surface foot of soil; and the manure to contain 70 per cent. of moisture. The amount of water-free manure used was 14.396 grams, the solution being prepared in the manner of plant solutions, making it up first in 3 liters which, after straining, were diluted to 12 liters.

The solution was prepared on October 7 and used the next day, when it was analyzed after adding the potassium nitrate, giving, by the colorimetric method, the amount stated in the table.

Amounts of water-soluble salts in a manure solution to which potassium nitrate was added.

	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million.								
Of solution	59.79	2.48	2.383	96.08	5.909	3.75	3.2	3.2	1.04
Of dry manure..	49839.	2067.2	1986.4	80089.	4925.5	3125.9	2667.4	2667.4	866.9

Five times the weight of the dry soil of this solution was used on each sample and it was caused to percolate through the sample three times in quick succession, the whole time required being from 30 to 45 minutes. The interval of contact is, therefore, short, but the whole solution was forced to come three times in contact with the soil by causing it to percolate under pressure through a layer about three-sixteenths of an inch thick.

As these soils had not ceased to yield salts to distilled water, at the time they were used for this experiment, although they had been 11 times washed, there has been made, from the amounts of salts recovered by the last washing, an estimate of what would probably have been recovered by another similar washing; and these amounts have been introduced into the tables which follow and used in computing the effect of the soils upon this solution.

The results found are given in the next table.

Amounts of salts absorbed by 8 soil types from a dilute manure solution to which potassium nitrate is added.

	K.	Ca.	Mg.	NO_3.	HPO_4	SO_4.	HCO_3	Cl.	SiO_2.
	In parts per million of dry soil.								
	Norfolk Sandy Soil.								
In soil at start	7.52	2.50	5.00	3.16	2.50	4.50	8.00	0.00	11.50
Added with solution ...	298.95	12.40	11.91	480.40	29.55	18.75	16.00	16.00	5.20
Total present............	306.47	14.90	16.91	483.56	32.05	23.25	24.00	16.00	16.70
Amount recovered.......	278.40	37.00	11.80	415.20	11.80	12.00	10.00	18.00	11.80
Change in soil...........	28.07	−22.10	5.11	68.36	20.25	11.25	14.00	−2.00	4.90
	Selma Silt Loam.								
In soil at start	12.50	1.50	4.95	3.03	8.50	9.50	8.00	0.00	14.50
Added with solution....	298.95	12.40	11.91	480.40	29.55	18.75	16.00	16.00	5.20
Total present............	311.45	13.90	16.86	483.43	38.05	28.25	24.00	16.00	19.70
Amount recovered.......	247.20	44.00	11.04	415.20	13.20	15.50	8.00	16.00	15.00
Change in soil...........	64.25	−30.10	5.82	68.23	24.85	12.75	16.00	0.00	4.70
	Norfolk Sand.								
In soil at start	5.85	2.75	4.35	2.42	6.50	7.50	8.00	0.00	12.00
Added with solution....	298.95	12.40	11.91	480.40	29.55	18.75	16.00	16.00	5.20
Total present............	304.80	15.15	16.26	482.82	36.05	26.25	24.00	16.00	17.20
Amount recovered.......	232.00	39.00	17.12	427.20	11.90	12.50	10.00	16.00	11.70
Change in soil.	72.80	−23.85	−.86	55.62	24.15	13.75	14.00	0.00	5.50
	Sassafras Sandy Loam.								
In soil at start	11.50	4.50	6.79	2.90	4.50	6.50	12.00	0.00	15.40
Added with solution....	298.95	12.40	11.91	480.40	29.55	18.75	16.00	16.00	5.20
Total present	310.45	16.90	18.70	483.30	34.05	25.25	28.00	16.00	20.60
Amount recoverd	184.00	46.00	15.92	392.80	10.60	13.00	14.00	14.00	15.00
Change in soil..........	126.45	−29.10	2.78	90.50	23.45	12.25	14.00	2.00	5.60
	Hagerstown Clay Loam.								
In soil at start	17.50	10.50	5.50	5.19	7.50	4.50	30.00	0.00	26.50
Added with solution....	298.95	12.40	11.91	480.40	29.55	18.75	16.00	16.00	5.20
Total present............	316.45	22.90	17.41	485.59	37.05	23.25	46.00	16.00	31.70
Amount recovered.	160.00	58.75	28.06	398.40	18.30	15.00	32.00	16.00	24.10
Change	156.45	−35.85	−10.65	87.19	18.75	8.25	14.00	0.00	7.60
	Hagerstown Loam.								
In soil at start	11.50	24.00	15.50	4.04	7.50	3.50	39.00	0.00	26.40
Added with solution....	298.95	12.40	11.91	480.40	29.55	18.75	16.00	16.00	5.20
Total present	310.45	36.40	27.41	484.44	37.05	22.25	55.00	16.00	31.60
Amount recovered.......	157.60	60.00	37.20	372.80	18.10	18.00	36.00	14.00	21.80
Change	152.85	−23.60	−9.79	111.64	18.95	4.25	19.00	2.00	9.80
	Janesville Loam.								
In soil at start	17.44	12.50	6.50	4.54	28.50	2.50	45.00	0.00	35.50
Added with solution....	298.95	12.40	11.91	480.40	29.55	18.75	16.00	16.00	5.20
Total present....	316.39	24.90	18.41	484.94	58.05	21.25	61.00	16.00	40.70
Amount recovered.	95.60	65.00	26.74	382.40	34.60	22.50	34.00	16.00	38.80
Change in soil...........	220.79	−40.10	−8.33	102.57	23.45	−1.25	27.00	0.00	1.90
	Miami Loam.								
In soil at start	13.50	10.50	7.50	3.82	18.50	1.00	24.00	0.00	36.50
Added with solution....	298.95	12.40	11.91	480.40	29.55	18.75	16.00	16.00	5.20
Total present............	312.45	22.90	19.41	484.22	48.05	19.75	40.00	16.00	41.70
Amount recovered.......	122.00	62.50	26.74	403.20	22.30	17.00	16.00	16.00	38.60
Change	190.45	−39.60	−7.33	81.02	25.75	2.75	24.00	0.00	3.10

If the computed amounts of change which occurred in these soils, as the result of contact with the solution, are brought together they appear as shown in the next table.

Amounts of change in the salt content of 8 soil types resulting from contact with a manure solution containing potassium nitrate.

	Norfolk Sandy Soil.	Selma Silt Loam	Norfolk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hagerstown-Loam.	Janesville Loam.	Miami Loam.
	In parts per million of dry soil.							
Changes in K	28.07	64.25	72.80	126.45	156.45	152.85	220.79	190.45
Changes in Ca	−22.10	−30.10	−23.85	−29.10	−35.85	−23.60	−40.10	−39.60
Changes in Mg	5.11	5.82	−.86	2.78	−10.65	−9.79	−8.33	−7.33
Changes in NO_3	68.36	68.23	55.62	90.50	87.19	111.64	102.57	81.02
Changes in HPO_4	20.25	24.85	24.15	23.45	18.75	18.95	23.45	25.75
Changes in SO_4	11.25	12.75	13.75	12.25	8.25	4.25	−1.25	2.75
Changes in HCO_3	14.00	16.00	14.00	14.00	14.00	19.00	27.00	24.00
Changes in Cl	−2.00	0.00	0.00	2.00	0.00	2.00	0.00	0.00
Changes in SiO_2	4.90	4.70	5.50	5.60	7.60	9.80	1.90	3.10
Total absorbed	151.94	196.60	185.82	277.03	292.24	318.49	375.71	327.07
Total dissolved	24.10	30.10	24.71	29.10	46.50	33.39	51.94	47.99

From this assembling of the data it is seen that all soils have absorbed large amounts of potash from the solution used, but the Norfolk Sandy Soil least and less than one-eighth that absorbed by the Janesville Loam, which produced the heaviest yields. While potash has been absorbed by all soils, in every case has lime gone into solution, and in larger quantities from the four soils which have given the largest amounts of lime from treatments with distilled water. So, too, have the four soils, yielding largest amounts of magnesia, under repeated washing, given this base over to the solution; but in three other cases magnesia was absorbed.

Very large amounts of nitric acid have failed to appear in the solution after contact with the soils and it has clearly been held back or transformed. Denitrification, in the biological sense, cannot have taken place to this extent, (1) because the soils themselves have been repeatedly dried at 120° C, and came to this experiment warm from the dry oven; (2) because sufficient time did not intervene for so much denitrification to have occurred as the result of vital activity. We were not able, with our reduced force at this time, to make tests for either ammonia or nitrous acid. The solution was analyzed in duplicate and there

is no reason to question the original amount present in the solution. Moreover, the amount of potassium nitrate added was made an indefinite amount more than one gram by adding enough to quickly tip a Springer Torsion balance against a gram weight. More potash, in every case but one, has been absorbed than is required to represent the chemical equivalent of the nitric acid disappearing from the solution.

The retention of phosphoric acid has not been very different with the different soils, but this, too, was the case in the instances cited from Voelcker. The solution contained phosphoric acid enough to represent 29.55 parts per million of the dry soil. In no case has this amount been absorbed; and the amounts left in the solution ranged between 10 and 22 parts per million of the soil, as may be seen from the general table, p. 155.

Comparatively large amounts of SO_4 were also fixed by the four poorer soils, the Janesville Loam being the only one which corresponds with the observations of earlier investigators.

Chlorine is the only negative radicle, existing in the solution used, which does not appear to have been fixed by the soils.

COMPARISON OF YIELDS WITH THE AMOUNTS OF ABSORBED AND DISSOLVED SALTS.

In the last two lines of the last table there are given the footings of the absorbed and dissolved salts for each soil type. In the next table these amounts are brought into comparison with the yields from the same soil types.

Comparison of yields with the amounts of salts absorbed by 8 soil types from a manure solution.

	Norfolk Sandy Soil.	Selma Silt Loam.	Norfolk Sand.	Sassafras Sandy Loam.	Hagerst'wn Clay Loam.	Hagerst'wn Loam.	Janesville Loam.	Miami Loam.
	In parts per million of dry soil.							
Potash absorbed	28.07	64.25	72.80	126.45	156.45	152.85	220.79	190.45
Total absorbed	151.94	196.60	185.82	277.03	292.24	318.49	375.71	327.07
Total dissolved	24.10	30.10	24.71	29.10	46.50	33.39	51.94	47.99
Corn, bu. per acre	36.26	38.89	29.55	29.51	52.88	54.68	80.43	69.31

When the four Northern soils are compared, as a group, with the four Southern soils, it is clear that much larger yields are associated with the power for larger absorption of potash and of total salts, and with the larger solution as well, where that has taken place. In the case of the individual members of the Northern group, too, the yields and absorption of total salts rise and fall somewhat together. The Selma Silt Loam and the Sassafras Sandy Loam, each of which is a stronger soil than its mate, have also a larger total absorption.

If water-soluble salts carried by soils are important factors of yield, and if the absorbed salts are still recoverable by degrees under field conditions, and available to crops, some such relations as have been pointed out should be expected to exist between the more and the less fertile soils.

ABSORPTION OF SALTS BY 8 SOIL TYPES FROM A SOLUTION OF ACME GUANO.

In another series of trials fresh field samples were washed in two ways, by percolation and by shaking in bottles, using a solution prepared from the acme guano, which had been applied to the fields at the rate of 300 lbs. per acre, on a series of the subplots on each of the 8 soil types.

The composition of the solution, as used upon the soils and determined by the methods employed, is given in the next table, where the amounts are stated in terms of the solution and in parts per million of the dry soil, on the basis that all the salts found in the solution added to the soil are absorbed by it. The usual ratio of 5 of solution to 1 of soil was observed.

Salts in solution of acme guano.

	K.	Ca.	Mg.	NO_3	HPO_4.	SO_4.	HCO_3.	Cl.	SiO_2.
	In parts per million.								
Of solution......	91.92	20.05	7.864	49.75	87.92	295.00	0.00	90.50	0.00
Of dry soil......	459.60	100.25	39.32	248.75	439.60	1475.	0.00	452.50	0.00

In this series, as in the last, the surface foot, only, of each soil type has been treated to the solution. It should be stated, also, that to this solution, as in the last, potassium nitrate was

added, 3 grams to 16 liters of solution, which also carried the soluble portion of 20 grams of the guano. The soils washed by percolation had the solution passed through them twice, under a pressure of 30 lbs., the time required being from 30 to 45 minutes. The other set of samples were treated exactly as though they were washed in distilled water, the usual three minutes, standing twenty minutes for decolorizing the solution with carbon black.

The changes which were observed, computed as in the last series, appear in the next table.

Soluble salts absorbed by 8 soil types during 30 to 45 minutes from solution of acme guano to which potassium nitrate had been added.

	Norfolk Sandy Soil.	Selma Silt Loam	Norfolk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hagerstown Loam,	Janesville Loam.	Miami Loam.
	In parts per million of dry soil.							
	Washed by percolation.							
Change in K	169.76	120.18	166.20	178.90	175.60	183.40	223.56	257.36
Change in Ca	279.80	262.50	83.00	38.30	130.00	95.00	103.80	80.00
Change in Mg	.36	2.46	−16.06	2.17	−41.65	−44.44	−50.53	−51.34
Change in NO_3	67.07	82.75	41.11	54.41	48.95	96.55	97.55	100.75
Change in HPO_4	258.90	248.74	252.96	201.80	293.40	306.10	254.60	265.95
Change in SO_4	95.50	97.50	−90.00	−83.00	131.50	−75.00	55.00	−18.00
Change in HCO_3	14.00	24.00	−8.00	4.00	24.00	10.00	6.00	−2.00
Change in Cl	−2.50	−2.50	−2.50	−2.50	−2.50	−7.00	−2.50	−2.50
Change in SiO_2	−25.10	−6.90	−13.10	−12.90	−4.90	−4.00	−2.90	−20.30
Average absorbed	885.39	838.13	543.27	475.58	803.45	681.05	740.51	704.06
Average dissolved	27.60	9.40	37.80	97.40	849.05	140.44	55.93	93.84
	Washed by shaking 3 minutes in bottle							
Change in K	154.56	172.98	164.60	170.10	176.96	187.40	217.16	266.16
Change in Ca	229.90	237.50	183.00	138.00	155.00	120.80	103.90	120.00
Change in Mg	1.46	2.28	.20	4.21	−46.44	−33.56	−40.25	−37.68
Change in NO_3	62.17	40.65	38.71	28.81	40.55	91.55	49.15	66.95
Change in HPO_4	213.70	236.74	216.56	317.40	313.10	299.70	246.20	233.85
Change in SO_4	−14.50	97.50	−15.00	67.00	65.00	35.00	−30.00	−18.00
Change in HCO_3	40.00	26.00	12.00	20.00	52.00	32.00	12.00	0.00
Change in Cl	17.50	27.50	32.50	32.50	22.50	−2.50	7.50	−2.50
Change in SiO_2	−16.00	−4.40	−22.80	−4.70	−2.30	−3.10	−11.00	−15.50
Average absorbed	719.39	841.15	747.57	978.02	825.11	766.45	635.91	686.96
Average dissolved	30.50	4.40	37.80	4.70	48.75	39.16	82.25	73.68

This set of samples, it must be remembered, had not been washed and therefore contained, before applying this solution, all of the salts normal to the field condition and, if the presence of those salts absorbed about the soil grains could have any influence on the absorption of other salts, results of a different char-

acter should be expected from those given in the previous section. Moreover, the solution has been made stronger as well as being of a different chemical nature.

It will be seen that potash has been absorbed in larger amounts in every case, as was to be expected from the larger amount used in the solution; and the soils giving the larger yields have, as a group, absorbed the largest amounts, although they are known, as demonstrated by the data of Bulletin B, to contain much more potash in the form capable of being recovered by repeated washing. In the next table there are placed the amounts of potash recovered by 11-times washing, together with the amounts absorbed here, and the sums taken as indicating, possibly, the lower limit of amounts of potash these soils are able to retain. At any rate, the sums will indicate the probable amounts of potash these samples did contain after having received this treatment.

Probable amounts of potash contained by 8 soil types after treatment with a solution of guano to which potassium nitrate was added.

	Norfolk Sandy Soil.	Selma Silt Loam.	Norfolk Sand.	Sassafras Sandy Loam.	Hagerstown Clay Loam.	Hagerstown Loam.	Janesville Loam.	Miami Loam.
	In parts per million of dry soil.							
Recovered with water..	133.25	209.58	161.49	177.57	221.12	215.96	266.96	213.55
Absorbed from solution	169.76	120.18	166.20	178.90	175.60	183.40	223.56	257.36
Total present......	303.01	329.76	327.69	356.47	396.72	399.36	490.52	470.91
Percentage relation....	61.78	67.24	66.81	72.68	80.88	81.43	100.00	96.01

These Janesville samples, after absorption, are therefore carrying nearly 500 parts per million of potash; the Lancaster samples nearly 400 parts per million; and the other four soils less than 350 parts per million, as an average.

The four Northern soils have retained an average of

439.38 — 329.24 & 110.4 parts per million

more potash, which, on the basis of 3,000,000 lbs. per acre-foot, represents 330 lbs. of what may be expected to be available potash per acre more than the Southern soils carry under these conditions.

With the amounts of salts present in the solution employed in this absorption series, and with that already present in the samples, there has been, in every case, a very large removal of lime from the solution, either by direct precipitation, or else by absorption. It can hardly have been thrown out as a sulphate, unless SO_4 already in the soil did the work, because the table shows that but little SO_4 was absorbed, except by the Hagerstown Clay Loam. Four of the soil types actually contributed SO_4 to the solution in the percolation set, as was the case in the other set. In the manure solution series, it will be recalled that there was but a single case where absorption of SO_4 did not take place, while lime went into solution.

Magnesia was forced into solution from the four Northern soils in both sets of this series, as it was in the manure series; and it went into solution from the Norfolk Sand in larger amounts in this than in the last series.

There is no exception, in either set of trials, to notable amounts of nitric acid disappearing from the solution; and here, again, its disappearance cannot be presumed to have resulted from denitrification due to biological agencies.

There appears to have been, in the first set of absorption trials of this series, a recovery of chlorine not shown by an ordinary examination of these soils, and the excess is so large in some cases that it seems legitimate to assume that absorbed chlorine was forced into the solution. The second set, however, points more strongly to an absorption of chlorine, unless, indeed, the results are admitted to represent irregularities in the method.

ABSORPTION OF SALTS FROM A PREPARED CHEMICAL SOLUTION BY 8 SOIL TYPES, AFTER HAVING BEEN 11-TIMES WASHED IN DISTILLED WATER.

After having washed the first series of soils 11 times in distilled water, they were again dried and afterward treated with the solution whose composition is given in the next table, prepared gravimetrically from chemicals in stock.

This solution was prepared to contain roughly the amounts of the several ingredients in parts per million that the soil moisture

would have carried had all of the materials found been in solution in the soil moisture when the samples were collected.

No chlorine or silica was included in this solution.

The solution was passed through the samples three times in quick succession and there was included in the series a sample of freshly crushed granite composed of orthoclase feldspar, muscovite mica and quartz. The amounts of absorption which took place are indicated in the next table.

Absorption of salts by 8 soil types and by freshly crushed granite.

	K.	Ca.	Mg.	NO_3.	HPO_4.	SO_4.
	In parts per million.					
Norfolk Sandy Soil	330	680	259	420	79	875
Selm Silt Loam	280	675	203	135	101	1875
Norfolk Sand	265	650	141	330	110	1125
Sassafras Sandy Loam	280	650	182	240	215	125
Average	289	664	196	281	126	1005
Hagerstown Clay Loam	575	700	183	240	133	1250
Hagerstown Loam	410	650	141	285	149	2375
Janesville Loam	652	575	294	285	63	375
Miami Loam	602	600	203	215	111	250
Average	560	631	205	256	114	1063
Crushed granite	230	575	163	80	69	125
In solution used	300	340	300	470	100	1600
In soil if all absorbed	1500	1700	1500	2350	500	8000

The solution used on these samples, it will be observed, is very much stronger than that used in the last series, but in these cases upon samples which had been freed of much of their readily water-soluble salts by repeated washing. The result was the throwing out of solution much larger amounts of every ingredient present except *phosphoric acid.* The amount of phosphoric acid present in this solution, however, was only12 parts per million more than in the one used in the guano series.

Another remarkable relation brought out in this series is that the absorption of potash from this solution by the four Northern soils averages nearly double what it does for the four Southern soils, and yet for all other ingredients the Southern soils have thrown out of solution more than the Northern ones have, if we except sulphates, upon which they are practically equal in their effects.

It should be recalled here that it is the potash ingredient of the soil which has shown the closest relation to yields as regards quantity recovered from the soil; and in all of these series the potash has been removed from solution in largest amounts by those soils which have produced the largest yields.

A limit appears to have been reached in this series where no determined ingredient was forced into solution from the soil, but rather that something from all was held back. This has not been the case in any other series presented.

The large irregularities shown in this series are, doubtless, to a considerable extent, due to the high concentration of the solution used, which required large dilutions before readings could be made by the methods. The aliquots have been large, therefore, and any error of setting greatly multiplied. The methods used are, of course, not adapted to such strong solutions, but they were the best which could be employed under the circumstances.

ABSORPTION OF SALTS BY BLACK MARSH SOIL.

Samples of soil were collected from a black marsh soil under three different crop conditions, (1) where corn was very poor; (2) where there was a fair average crop, and (3) where the corn had all died, possibly because the soil had been too wet, and was at the time supporting a rank growth of weeds.

These soils were treated with two different solutions the usual time for washing soil samples, and by the same method, except that in these cases solutions instead of distilled water were employed.

In the next table there are given the results secured from one of these absorption series, together with other data.

Salts absorbed from a solution, during 20 minutes, by black marsh soil in three productive conditions.

	K.	Ca.	Mg.	No_3	HPO_4	SO_4.	HCO_3	Cl.	SiO_2
	In parts per million of dry soil.								
	Recovered from the soil with distilled water								
(1) Under poor corn.....	46.18	306.00	93.84	519.20	12.80	520.00	114.00	30.00	50.80
(2) Under good corn.....	60.96	160.00	65.28	354.40	32.00	178.00	124.00	44.00	98.90
(3) Under no corn......	29.84	160.00	46.92	52.60	20.00	240.00	282.00	16.00	59.70
	Added to the soil in the solution.								
Solution A..............	213.60	205.00	116.10	181.60	2352.0	392.0	80.0	304.0	63.3
	Absorbed from the solution by the soil.								
(1) Under poor corn	83.68	−59.00	14.32	−8.00	167.20	−168.0	64.0	−10.0	−56.6
(2) Under good corn....	83.36	−25.00	60.08	115.20	200.00	−100.0	160.0	−8.0	−19.0
(3) Under no corn.......	107.84	10.00	31.32	29.40	106.40	−18.0	162.0	−12.0	54.0
	Added to the soil in the solution.								
Solution B..............	256.8	204.0	114.1	259.6	249.6	408.0	8.0	308.0	3.0
	Absorbed from the solution by the soil.								
(1) Under poor corn. ...	84.12	70.0	14.96	−51.6	120.8	−132.0	54.0	−6.0	38.9
(2) Under good corn....	85.36	19.0	54.98	33.2	127.2	−94.0	84.0	−16.0	87.6
(3) Under no corn......	80.84	−16.0	37.64	48.2	134.4	28.0	114.0	−12.0	32.3

The two solutions were made up to have approximately the same concentration but in the (A) solution potassium nitrate was used with calcium chloride; while in the (B) solution calcium nitrate and potassium chloride were used. The other ingredients were calcium phosphate ($CaHPO_4$, $2H_2O$) and magnesium sulphate ($MgSO_4$, $7H_2O$).

It will be seen from the table that the soil, under the good corn, yielded to distilled water most potash, most phosphoric acid, most chlorine and most silica; while the soil under the poor corn yielded most lime, magnesia, nitric acid, and sulphuric acid; and the soil under no corn gave least potash, magnesia, and chlorine.

Potash was absorbed from both the nitrate and chloride in nearly the same amounts by the three conditions of soil, except that the "no corn" soil took up 108 parts per million as the nitrate and only 80 parts from the chloride, throwing out the

same amount of chlorine in both cases and absorbing most nitric acid where it was combined with lime.

Lime was thrown into solution by the soils under good and poor corn, where it went in as chloride but was absorbed as the nitrate; while the "no corn" soil showed the reverse relation.

Magnesia was absorbed in largest amount by the soil under good corn and in least amount by that under poor corn.

Nitric acid was thrown into solution by the poor soil in both cases, but in largest amount when it went in with the lime. It was absorbed in much the largest amount from the potash salt by the good corn soil but in least amount as the lime nitrate.

The good corn soil has absorbed more phosphoric acid than the poor corn soil in both cases and more than the "no corn" soil in one case.

Another set of these same soils were treated with the same solution in the same manner, except that they were left in contact over night or during about 18 hours, instead of 20 minutes, as in the preceding case. The results of these determinations are given in the next table.

Salts absorbed from a solution during 18 hours by black marsh soil in three productive conditions.

	K.	Ca.	Mg.	NO_3.	HPO_4	SO_4.	HCO_3	Cl.	SiO_2.
	In parts per million of dry soil.								
	Absorbed from solution "A" by the soil.								
(1) Under poor corn	-62.62	41.00	8.52	172.80	197.60	−288.0	−234.0	−18.0	24.9
(2) Under good corn	22.56	−85.00	70.00	292.80	187.20	−200.0	20.0	−12.0	82.7
(3) Under no corn	190.64	-165.00	18.84	187.32	174.40	−98.0	−414.0	−16.0	45.4
	Absorbed from solution "B" by the soil.								
(1) Under good corn	104.58	30.0	9.36	198.00	182.40	−272.0	−294.0	−32.0	13.7
(2) Under poor corn	88.16	−66.0	58.08	268.40	160.80	−254.0	−116.0	−44.0	74.6
(3) Under no corn	119.84	−66.0	−.12	249.00	214.40	−152.0	-510.0	−36.0	9.1

If comparison is made of the changes which have occurred during the 20 minute and the 18 hour intervals, it will be seen that the same marked differences are shown.

	Under Poor Corn		Under Good Corn		Under No Corn.	
	Solution A.	Solution B.	Solution A.	Solution B.	Solution A.	Solution B.
	In parts per million of dry soil.					
	Changes in potash.					
During 20 minutes	83.68	84.12	83.36	85.36	107.84	80.84
During 18 hours	−62.62	104.56	22.56	88.16	190.67	119.84
Difference...............	−146.30	20.44	−60.80	2.80	82.83	39.00
	Changes in lime.					
During 20 minutes	−59.0	70.0	−25.0	19.0	10.0	−16.0
During 18 hours	41.0	30.0	−85.0	−66.0	−165.0	−66.0
Difference	100.0	−40.0	−60.0	−85.0	−175.0	−50.0
	Changes in magnesia.					
During 20 minutes	14.32	14.96	60.08	54.88	31.32	37.64
During 18 hours............	8.52	9.36	70.00	58.08	18.84	−.12
Difference..............	−5.80	−5.60	9.92	3.20	−12.48	−37.76

From this grouping of the data it is seen that the tendency has been for the absorption of potash to increase with the longer interval of contact, and for the lime and magnesia to be absorbed less, or else more to go into solution. Under the influence of the "A" solution, however, the fixation of potash has been less, or more has gone into solution with two of the soil conditions, namely, under the poor and good corn; at the same time, the soil under the poor corn has fixed lime instead of throwing it into solution.

If we compare the changes in nitric and phosphoric acid, and silica, they appear as below:

	Under Poor Corn		Under Good Corn		Under No Corn.	
	Solution A.	Solution B.	Solution A.	Solution B.	Solution A.	Solution B.
	In parts per million of dry soil.					
	Changes in nitric acid.					
During 20 minutes	−8.0	−51.6	115.2	33.2	29.40	48.2
During 18 hours	172.8	198.0	292.8	268.4	187.32	249.0
Difference	180.8	249.6	177.6	235.2	157.92	200.8
	Changes in phosphoric acid.					
During 20 minutes	167.2	120.8	200.0	127.2	106.4	134.4
During 18 hours	197.6	182.4	187.2	160.8	174.4	214.4
Difference	30.4	61.6	−12.8	33.6	68.0	80.0
	Changes in silica.					
During 20 minutes	−56.6	38.9	−19.0	87.6	54.0	32.3
During 18 hours	24.9	13.7	82.7	74.6	45.4	9.1
Difference	81.5	−25.2	101.7	−13.0	−8.6	−23.2

Here it is seen that everywhere more nitric acid has been fixed during the longer interval or else—and which is probably the case—more denitrification has occurred. More phosphoric acid has also been fixed, except from the "A" solution, by the soil under "good corn." In the case of silica it has been less extensively fixed during the longer period, except in those two cases where, during the 20-minute period, it was forced into solution and where less potash was fixed, or the potash had been actually forced into solution at the end of the 18 hour period.

Comparing the changes which occurred during the two periods in the case of the remaining three negative radicles SO_4, HCO_3 and Cl, we have the results shown in the next table.

	Under Poor Corn		Under Good Corn		Under No Corn.	
	Solution A.	Solution B.	Solution A.	Solution B.	Solution A.	Solution B.
	In parts per million of dry soil.					
	Changes in SO_4.					
During 20 minutes	−168	−132	−100	−94	−18	28
During 18 hours	−288	−272	−200	−254	−98	−152
Difference	−120	−140	−100	−160	−80	−180
	Changes in HCO_3.					
During 20 minutes	64	54	160	84	162	114
During 18 hours	−234	−294	20	−116	−414	−510
Difference	−298	−348	−140	−200	−566	−624
	Changes in chlorine.					
During 20 minutes	−10	−6	−8	−16	−12	−12
During 18 hours	−18	−32	−12	−44	−16	−36
Difference	−8	−26	−4	−28	−4	−24

In these three cases the negative radicles have gone into solution in increasing amounts in all cases with the longer contact of the solutions with the soil. It is also to be observed that the changes have been, throughout, greatest with the "B" solution where the nitric acid went in, in combination with lime, as was the case also with nitric and phosphoric acids, only these decreased rather than increased in the solution.

Attention should be called here, as was done in a previous section, p. 54, to a well marked indication of chlorine, previously absorbed by the soil and not readily recovered by single washings in distilled water, being forced into solution under the conditions to which the soils were here subjected. Indications of absorbed chlorine have also been pointed out in Bulletin "B," in connection with observations made in the preliminary study and development of the methods. An alternate hypothesis, in connection with this series of data, would be that the decomposition of organic matter attendant upon the denitrification which occurred in these cases, may have liberated both combined chlorine and perhaps SO_4, from difficultly soluble compounds, thereby increasing the amounts in the solutions after contact with the soils.

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SOIL MANAGEMENT.*

"The three papers here printed have been fused departmental publication by the Chief f the Bureau of Soils."

In glancing at this note on the title page f this pamphlet of 168 pages, the reader is aturally struck with the query, why the U. . Department of Agriculture should decline o publish the results of the work of such a an as King, working under its auspices. Has the salt indeed lost its savor? Both American and European scientists have been ccustomed for many years to regard with onfidence and respect the work and publications of the man upon whom, by common consent, the mantle of Wollny has fallen since the remature death of the soil physicist of Germany. It is certainly worth the while of very worker in agricultural science to see and judge for himself whether a star has been clipsed or blotted out from the scientific rmament, and if so, from what cause.

We are, at the outset, somewhat reassured s to the totality of the conjectured eclipse, y finding that the three rejected bulletins are ut a portion of a series of six forming the eport of King, as head of the Division of oil Management, for the years 1902 and 1903. ince three out of the six have been accepted y the department for publication, it is evident that King's right hand has not wholly lost its cunning during these two years. What, hen, is the matter with Bulletins D, E and F, ere presented to us by the author at his personal expense and risk, and as he expressly tates, in their original form?

As it happens, the rest of the series, bulletins B, C and G, have not yet reached publication by the bureau of soils. We must, therefore, rely upon the intrinsic evidence contained in the three now before us, to settle the reason for their rejection.

In his preface the author reticently says that the 'adequate discussion was withheld in order to avoid, as far as possible, antagonizing the published views of the Bureau' (of Soils); and hence the three papers are published without general comments. It is to the conclusions deducible from the facts given, then, that we must look for the substance of these papers, and for the possible cause of their falling under condemnation.

Bulletin E, the first in the pamphlet and the most important of the three, treats of the results obtained in the fertilization with stable manure, in different multiple proportions, of eight different types of soils. The experiments were conducted on eight two-acre plots, located respectively near Goldsboro, N. C., Upper Marlboro, Md., Lancaster, Pa., and Janesville, Wis., and representing two groups of four each, 'strongly contrasted in their native productive capacities, in order that strongly marked differences might be dealt with.' The dressings of barnyard manure used were at the rate of five, ten and fifteen tons per acre. The crops grown were potatoes and corn, with a series of unmanured check-plots between, in each case.

The crops from each series of plots were weighed, mostly both in the green and in the dry condition; and concurrently, the kinds and amounts of soluble salts extractable by water from the soils of each of the plots before and at different intervals after the application of the manure, were determined according to the

* 'Investigations in Soil Management,' being hree of six papers on the influence of soil management upon the water-soluble salts in soils, nd the yield crops, by F. H. King, Madison, Visconsin. Published by the author, with permission of the Secretary of Agriculture.

delicate methods used in the investigations of aqueous soil extracts.* Moreover, the amounts of the several substances contained in the soil extracts, present in the sap of the plants themselves, were likewise determined, in order to ascertain the relations between the soil solutions and the substances taken up by the crops.

It is not easy for the outsider to detect anything reprehensible in this well-considered plan of operations. It seems to be admirably conceived for the determination of the relation of the soil solutions to plant nutrition and crop production under normal, practical conditions. The details given regarding the actual carrying out of the experiments are equally unexceptionable, except as concerns some points in respect to which, apparently, there was interference of some sort with the plan; *e. g.*, in the matter of making chemical analyses of the stable manure used at the several localities. But however regrettable, this and some other omissions, apparently imposed by superior authority, do not vitiate, to any material extent, the conclusions arrived at by King.

The plan and methods of experimentation being thus unexceptionable so far as any one examining the record given can judge, the only question remaining is whether the conclusions deduced from the experimental results are justified, and whether these are in conflict with practical or scientific experience, or with common sense. Of these conclusions it will be best to give the chief ones in the words of the author.

After giving, on page 5, a table showing the percentage relations of crop yield under different fertilizations, he says: 'It will be seen that in the case of the poorer soils there is a percentage difference of 46 between the yields of the fifteen-ton subplots and those to which nothing has been added; but a difference of only eighteen on the stronger soils.' Recalculating these results on the next page so as to show their relations more clearly, he adds: 'These results show that both relatively and absolutely, adding fertilizers to the poorer soils has had a greater effect than the same treatment with stronger soils.' Farther on, afte giving a table of the several yields of wate free shelled corn, he says: "It is here seen tha on the four poorer soils, there is a systemati difference in the yield of water-free shelle corn, closely related to the fertilizers applie to the soil. The group of four stronger soil do not show, throughout, this systematic rela tion." Photographic views of the corn on th growing plots show these differences clearly i the growth of the plants.

The only criticism that could be, perhaps made of the work leading to these conclusion from an outside point of view, is that the are so clearly and thoroughly in accord wit all former experience, both practical and ex perimental, that they are largely foreseen.

Then follows the record and discussion o corresponding experiments with potatoes which yield practically the same results an conclusions.

Then are given the results of analyses o leachings of the same soils upon which these crops had been grown. The results are pre sented in a table, from which "it is very clea that the effect of different amounts of stabl manure applied to these soils * * * has been such upon the recovery of the water-solubl salts as to enable the same treatment to re move different amounts from different fertili zations. * * * There is a clear quantitative relation, too, between the yields and the salts recovered, these (the former) increasing where the essential ingredients of plant food are higher."

King also details the experiments made with small (four-pound) samples of soils mixed with much larger amounts of the same manure, the leachings of which after 65 days, gave, in general, results corresponding to those obtained from the field tests; and he discusses in detail the apparent effects upon the solubilities of the several ingredients of plant food, and the influence upon the formation and reduction of nitrates; showing that there is no direct ratio between the amount of manure added and the nitrates found in the different soils. He determines and discusses, likewise, the relation of the salts added to the soils in the

* Bulletin No. 22, Bureau of Soils.

manure to those recovered by leaching, all vouched for by full analytical data.

Finally, King shows the effects upon the plants of different doses of manure, with respect to the water-soluble salts recoverable from the plants themselves. In both cases the influence of manuring is mainly seen to be a direct one, as has, in fact, already been shown by Godlewski. "It is thus shown that the crops on the manured ground have recovered 29 per cent. more potash from the four stronger soils, and 40 per cent. more from the poorer soils, where the fifteen tons of manure had been applied." Lime and magnesia, on the contrary, were diminished where the potash was increased.

What may be considered the final summing-up of this bulletin is given by King in the following paragraph on page 60, the last but one:

> The observations here presented, both upon the soils and upon the plants which had grown upon them make it clear that when farmyard manure is applied to fields it has the effect not only of increasing the yields, but at the same time of increasing the amounts of water-soluble salts which can be recovered from the soils themselves and from the plants which have grown upon them.

I have thought it necessary to present to the readers of SCIENCE somewhat in detail the contents of this bulletin E, in order to show what kind of work it is to which the bureau of soils refuses its *imprimatur*. To the unofficial mind—the *beschränkte Unterthanenverstand*—it appears as an admirable piece of work, in a line but little touched by agricultural investigators thus far, and manifestly likely to lead to important new lights, as well as to definite quantitative corroboration of old ones. As to bulletins D and F, respectively, on 'The Absorption of Water-soluble Salts by Different Soil Types' and on 'The Movement of Water-soluble Salts in Soils,' they are in a measure complementary to bulletin E, affording most interesting side-lights upon the general subject of the latter; they are altogether of similar high scientific grade. They also figure among the 'rejected papers.'

The clew to that rejection evidently lies in 'the published views of the Bureau of Soils,' which King for the time being does not desire to antagonize by discussion, as stated in the preface. What those views are is not specified; but it is easy to see that the results of King's work are wholly incompatible with the remarkable utterances of 'Bulletin 22,' now well known to all interested in agricultural science. Essentially, that bulletin promulgates the doctrine that while fertilizers 'do sometimes, and even frequently,' seem to increase production, yet since, according to data given therein, the aqueous soil solution is always of the same composition in all soils, it follows that all soils contain sufficient available plant food to maintain productiveness indefinitely; and that the moisture supply is the one controlling condition, climate permitting.

Such being the official, orthodox doctrine, it becomes clear why especially bulletin 'E,' showing pointedly the very reverse of the official doctrine to be true, could not receive the official approval and *imprimatur*. And that a man of King's standing and reputation could not, under such circumstances, do otherwise than tender his resignation, to take effect after his report had been completed and submitted, is obvious. This having been done, the Bureau of Soils is now rid of a contumacious, insubordinate person, who refuses to subscribe to his chief's scientific dicta as set forth in Bulletin 22; which, it is well known, has not received the assent of a single scientist of weight, and has been controverted and repudiated both in America and Europe by all who have taken any notice of it.

But worse than the ill-founded hypotheses of the head of one of the most important bureaus of the Department of Agriculture, which, moreover, receives and spends one of the largest appropriations in the budget of that department, is the return to medievalism indicated in the case before us. It is not only that of a deliberate attempt to suppress the truth, but it indicates on the part of the morally responsible head of that bureau a more than child-like confidence in the permanent success of the obscurantist régime such as is practiced

ad defended by Pobyedonostseff. Yet it is oubtful that even the latter, or the puissant ead of the Russian Empire himself, would ndertake to pass the censor's black brush over nductive scientific papers like these of King. It is impossible to conceive that in the ventieth century, and especially in a country aiming to be progressive *par excellence*, such régime should be allowed to continue for any length of time. King has uttered his '*e pur si muove*' by the publication of his rejected papers; it now behooves the scientific men of the country to voice their emphatic protest against the dictation of official orthodox science of any kind, from headquarters at Washington.

E. W. Hilgard.

Berkeley, Calif.,
September 29, 1904.

C M